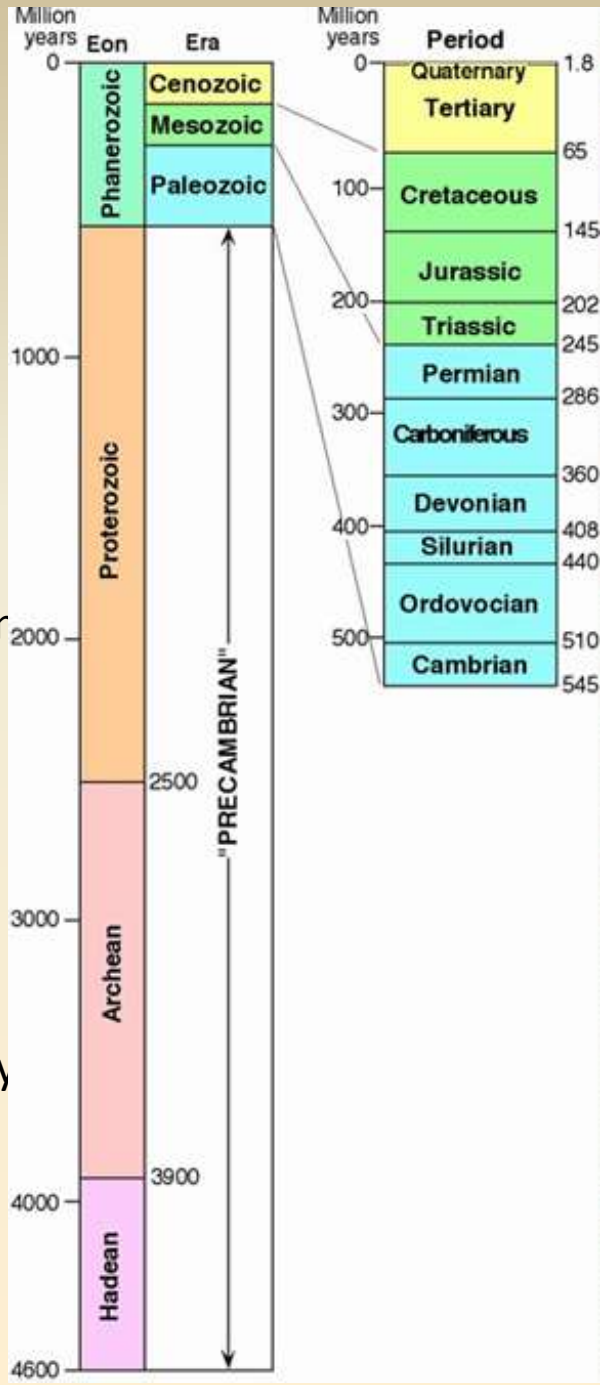
Mesozoic

251 to 65.5 MYA

Geological Eras

We can divide the history of life on Earth into six main stages:

1. Hadean Era: from the formation of the Earth about 4.6 billion years ago until about 4 billion years ago. The Earth's surface is constantly bombarded by large objects which repeatedly melt the whole surface, making life impossible.
2. Archean Era: from 4 to 2 billion years ago (very roughly). Origin of life, all life is single celled bacteria. No oxygen in the atmosphere.
3. Proterozoic Era. 2 billion until 550 million years ago. Oxygen appears in the atmosphere and builds to approximately the present level of 21%. Eukaryotes appear. No hard parts: bone, teeth, shells, so very few fossils.
   - the first three eras are collectively called the Pre-Cambrian era
4. Paleozoic Era. 550 to 250 million years ago. Fossils appear, complex multicellular organisms, invasion of the land by plants and animals.
5. Mesozoic Era. 250 to 65 million years ago. Appearance of mammals and flowering plants, but the land is dominated by dinosaurs (reptiles).
6. Cenozoic Era. 65 million years ago until present. Land dominated by mammals and flowering plants.

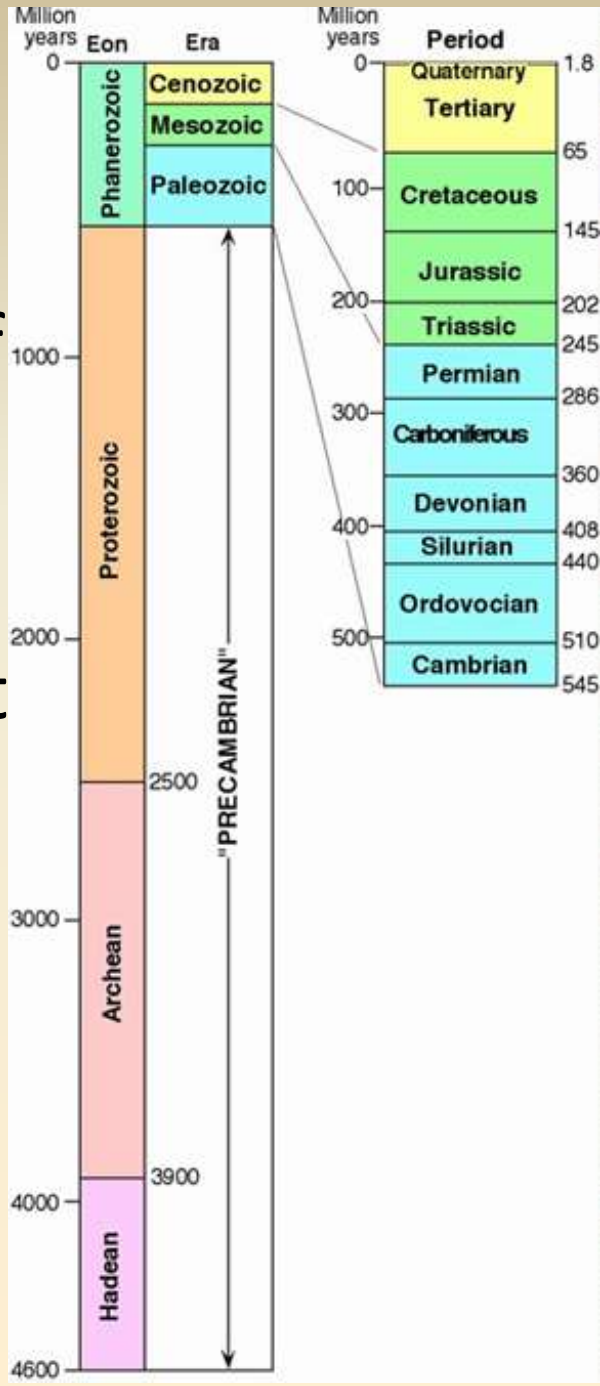


Geological Eras

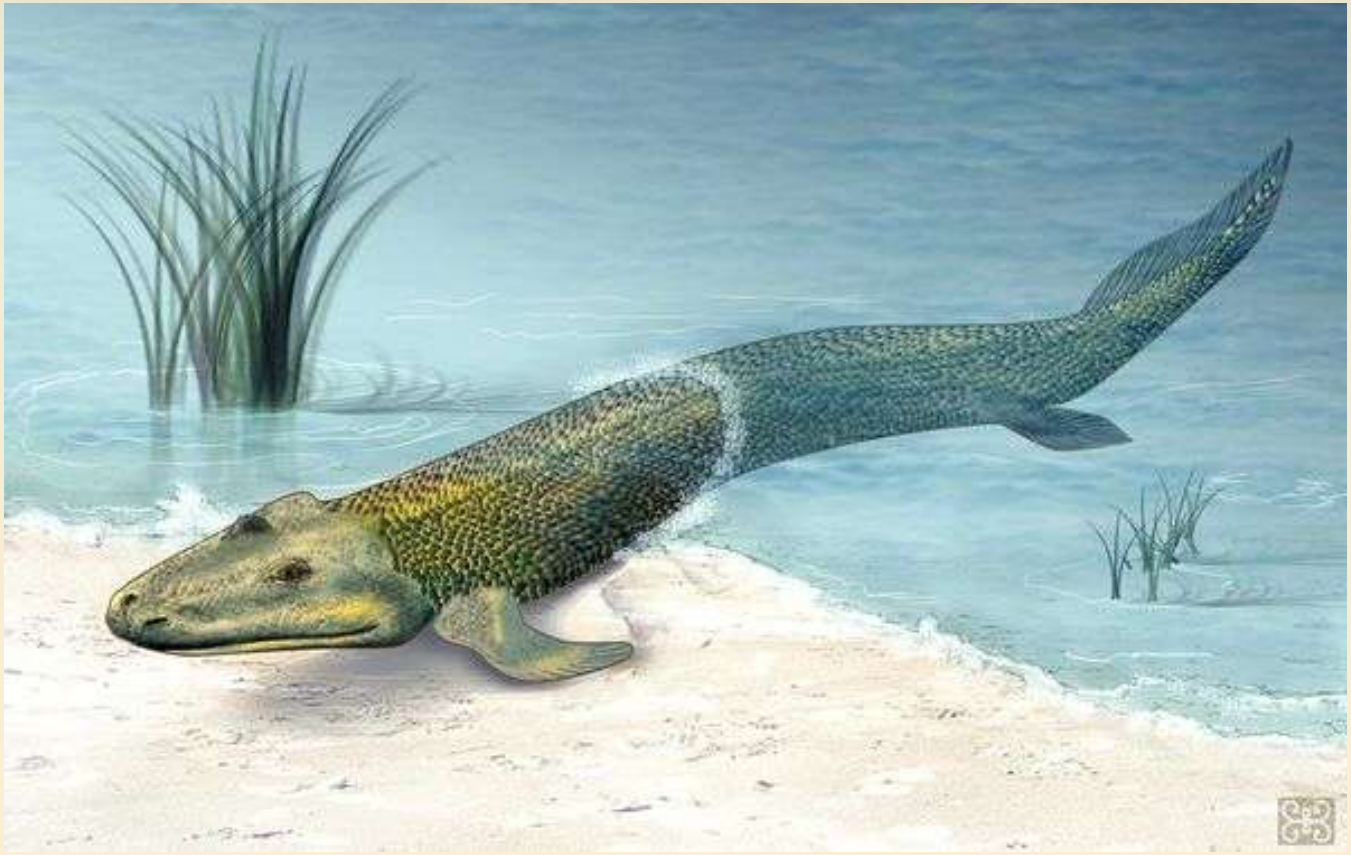
Paleozoic Era. 550 to 250 million years ago. Fossils appear, complex multicellular organisms, invasion of the land by plants and animals.

Mesozoic Era. 250 to 65 million years ago. Appearance of mammals and flowering plants, but the land is dominated by dinosaurs (reptiles).

Cenozoic Era. 65 million years ago until present. Land dominated by mammals and flowering plants.

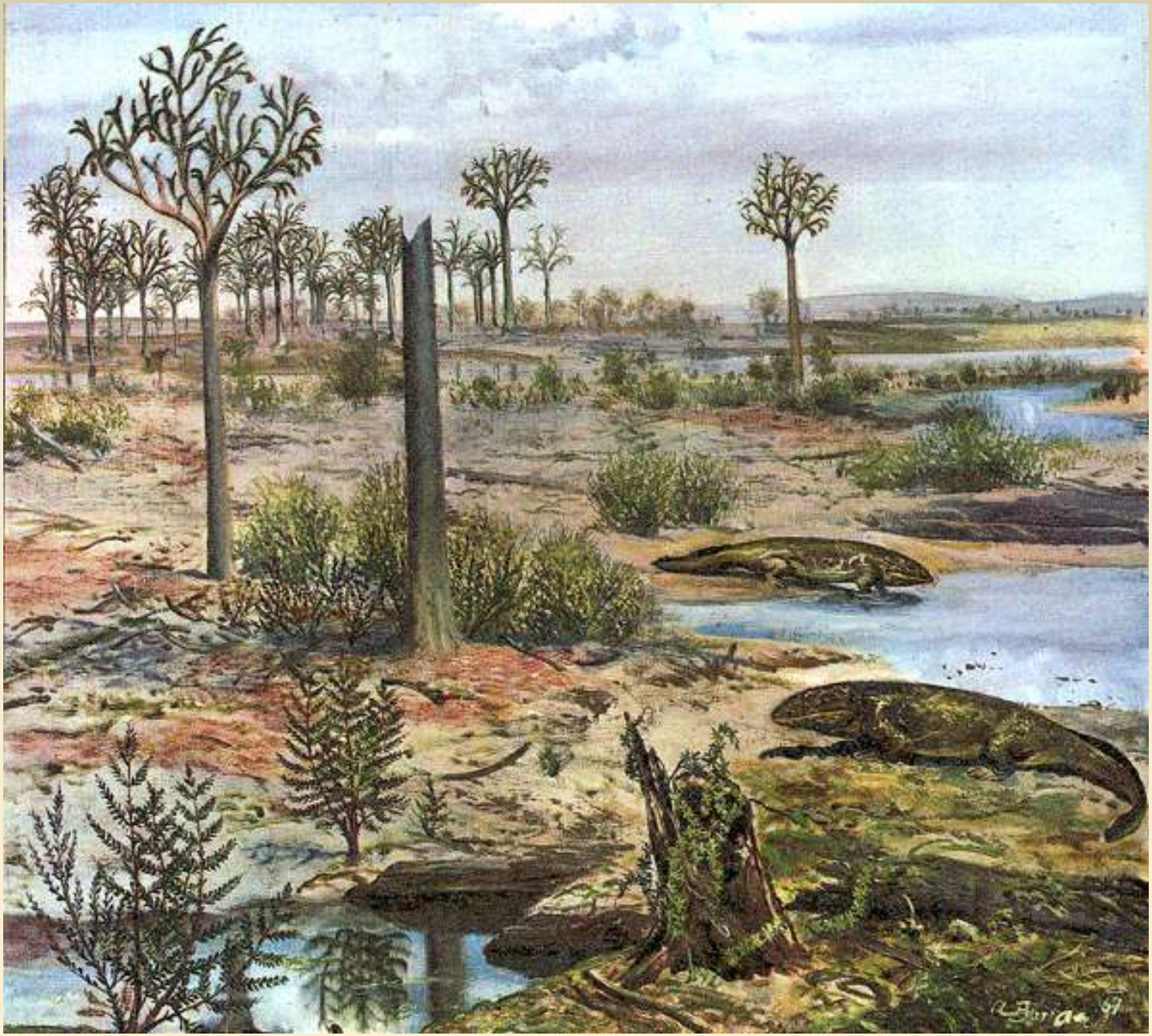


Paleozoic
Cambrian Explosion
Amphibians



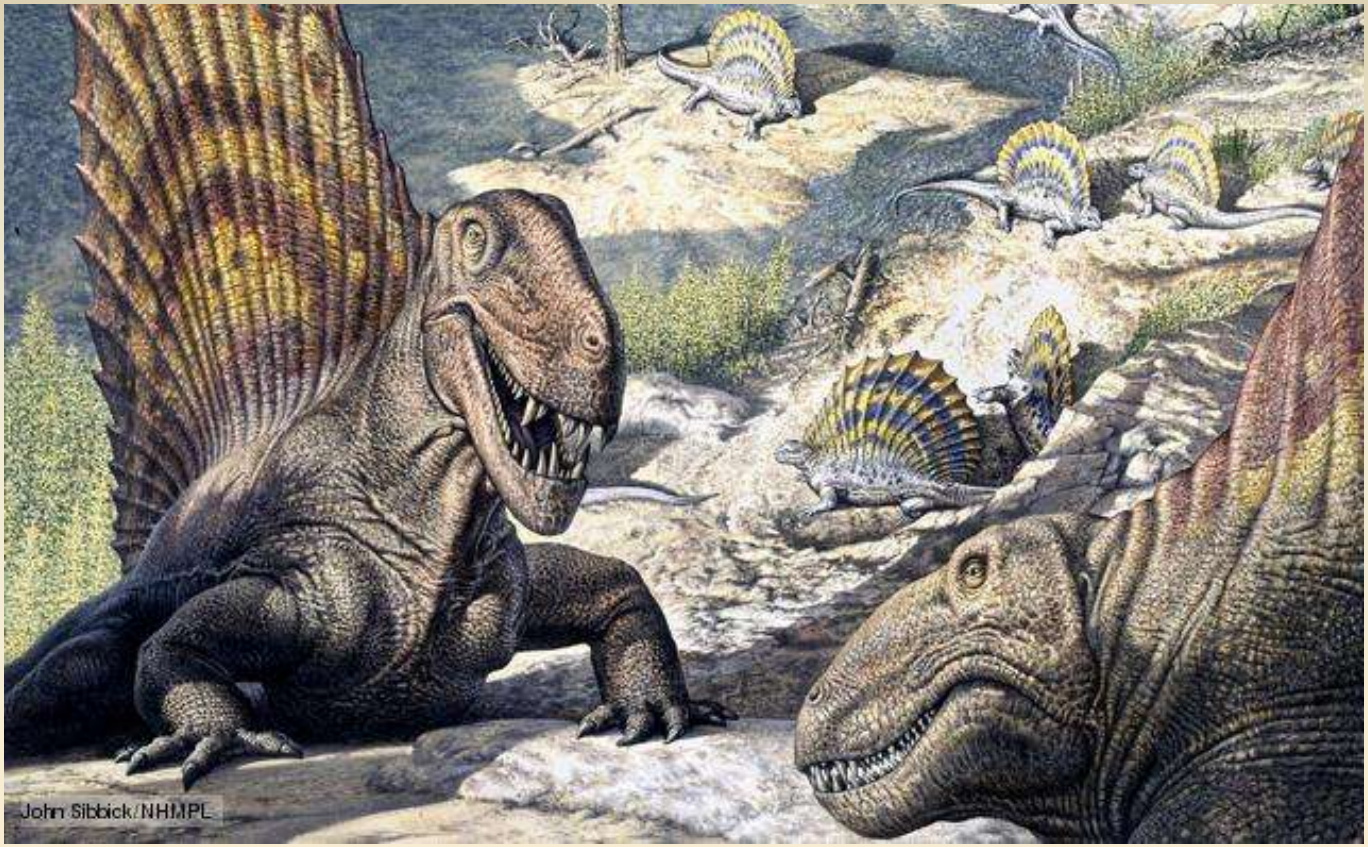
Tiktaalik – transitional fish-amphibian

Devonian Forest Landscape



Carboniferous Forest – 300 mya

Synapsids – Mammal-like Reptiles



An offshoot of the ancestors of the reptiles that includes all of the mammals and the mammal-like reptiles. Don't fit neatly into either category. They include the sail-backed *Dimetrodon* and *Edaphosaurus*, the tusked dicynodonts and the ancestors of all today's mammals. Synapsids ruled the land in the Permian period, becoming the largest and most numerous terrestrial vertebrates

Permian Mammal-like Reptiles

Dominated the land vertebrate fauna of the Permian and early Triassic before losing ground to the diversifying dinosaurs and other archosaurs.

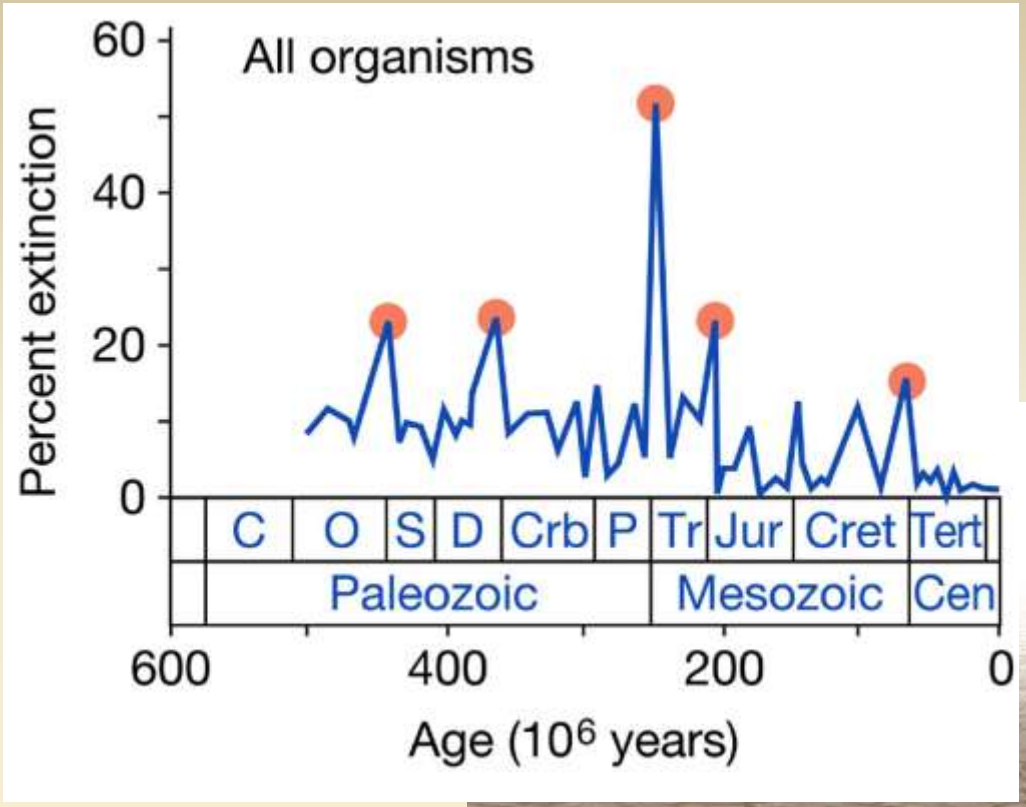
Therapsids

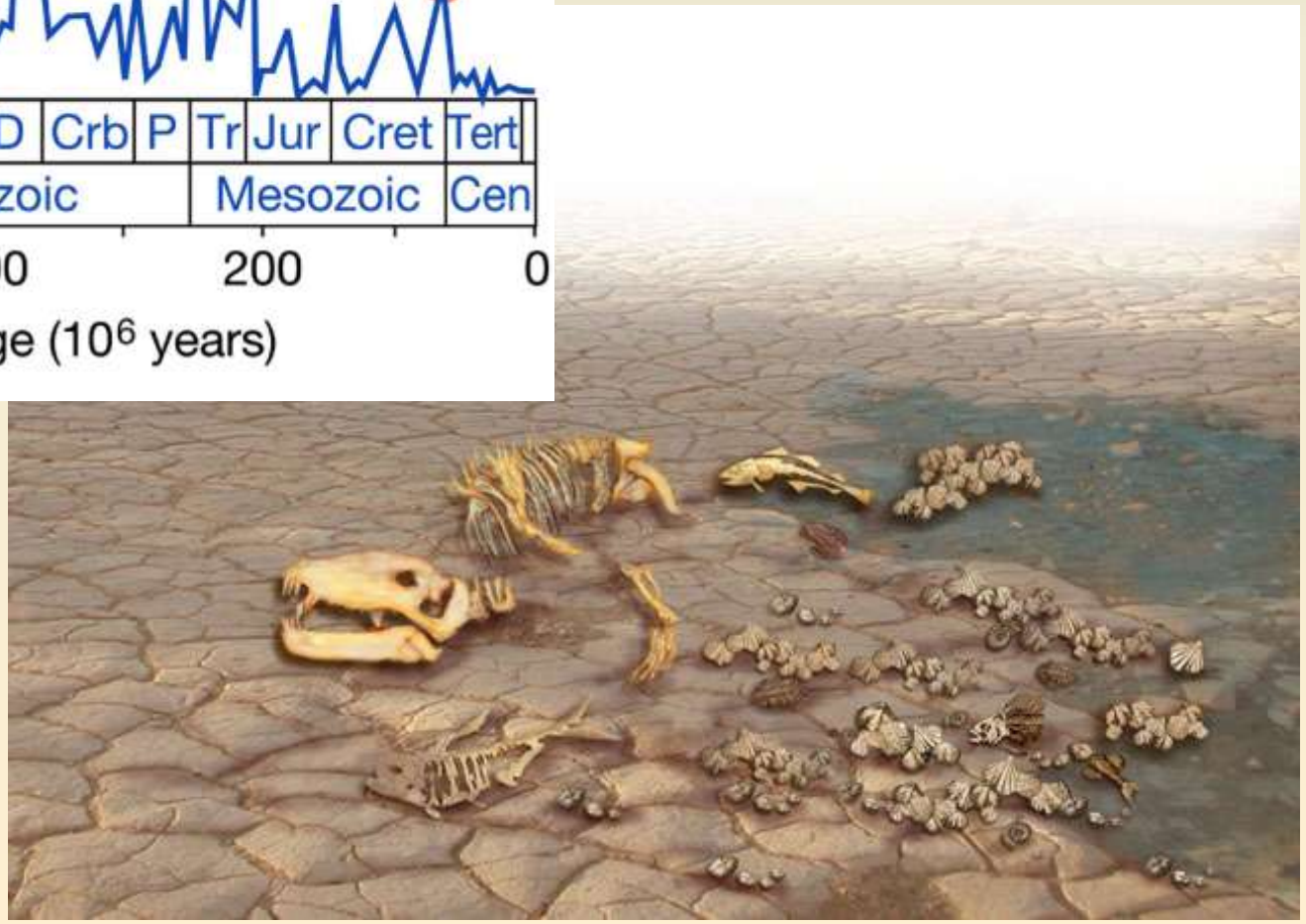
The therapsids rose to prominence in the Permian to become the most successful land animals of their day. The secret of their success was in their teeth, as therapsids evolved new and better methods of chewing plant and animal food. However, the group took a hammering in the mass extinction at the end of the Permian, and was sidelined for millions of years as the dinosaurs diversified.

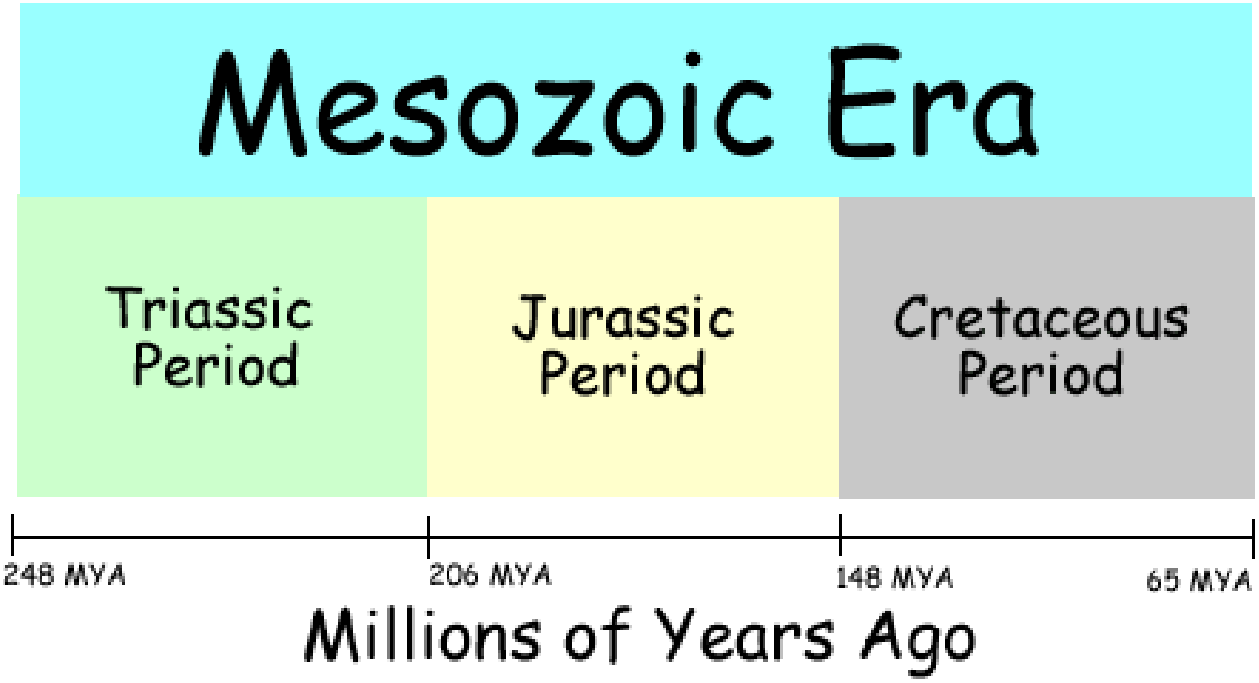
Cynodonts – late Permian

It was during the evolution of the cynodonts that many things typical of mammals arose: their jaw structure, the hammer, anvil and stirrup bones of their inner ear, and - the secret of their success - their efficient chewing teeth. Things which don't fossilize so easily, such as warm-bloodedness, furry bodies and milk production also probably arose in the pre-mammalian cynodonts.

Permian Extinction






Mesozoic Era
Triassic Period
Jurassic Period
Cretaceous Period
248 MYA
206 MYA
148 MYA
65 MYA
Millions of Years Ago

The Diversity of Life in the Mesozoic

- At the beginning of the Mesozoic Era, diversity (as indicated by the number of genera) was low, following the Permian extinctions. Recovery from the Permian extinctions was slow for many groups.
- In the oceans, the molluscs re-expanded to become much more diverse than in the Paleozoic, and modern reef-building corals, swimming reptiles, and new kinds of fishes appeared.
- A mass extinction occurred at the end of the Triassic Period. The **Triassic extinction** affected life on the land and in the sea, causing about 20% of all marine animal families to become extinct.

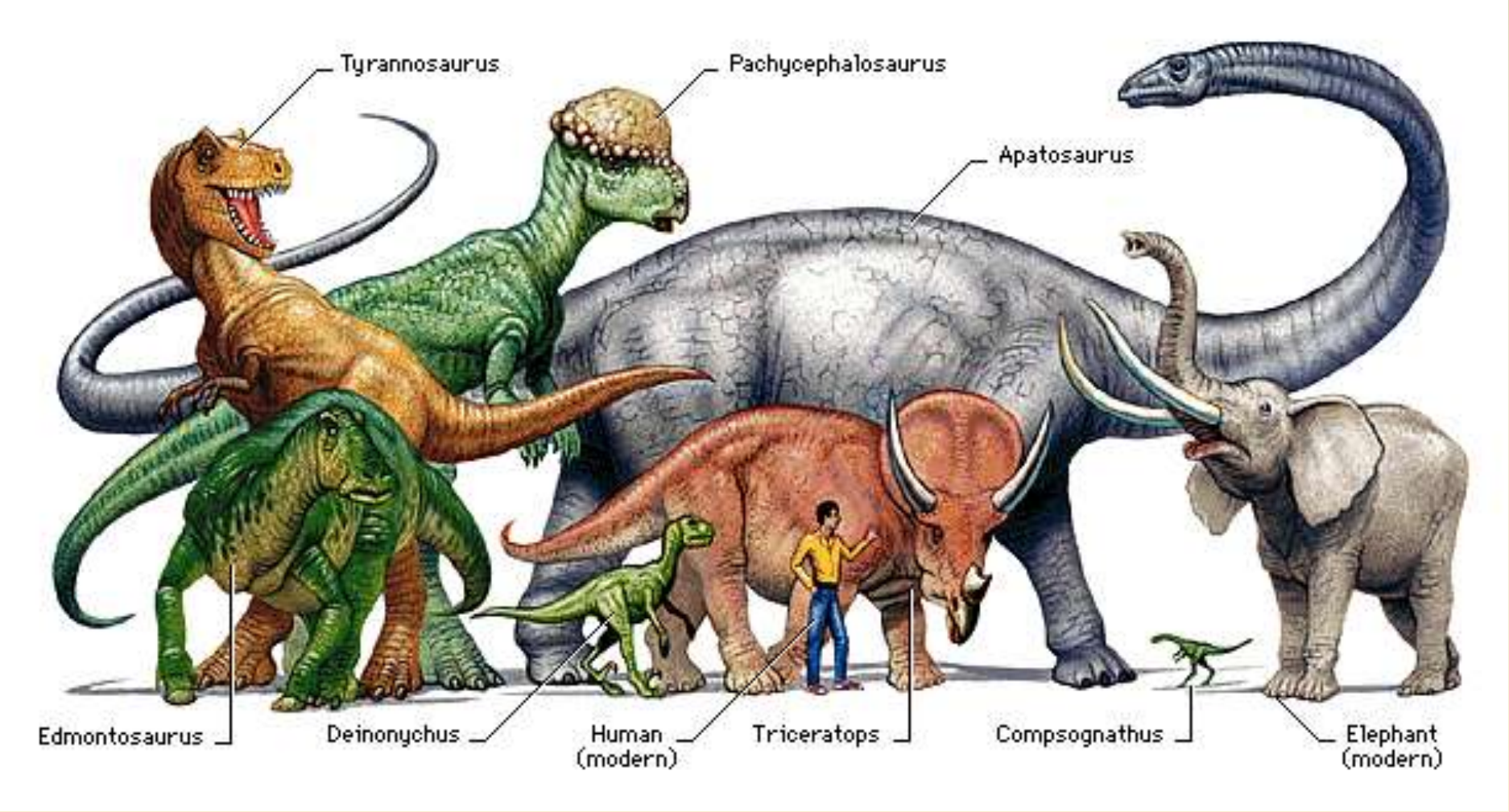
The Diversity of Life in the Mesozoic (cont)

- Diversity increased in the Jurassic, and rose quickly during the Cretaceous to higher levels than had existed previously.
- Much of this expansion in diversity was related to the appearance of **new types of marine predators**, including advanced teleost fishes, crabs, and carnivorous gastropods.
- Life in the Cretaceous consisted of a mixture of both modern and ancient forms.
- A major extinction event occurred at the end of the Cretaceous Period, affecting both vertebrates and invertebrates, on land and in the sea.

Age of Reptiles

- The dinosaurs existing during the Mesozoic Era
  - fascinate nearly everyone
- Ever since Sir Richard Owen
  - first used the term ***dinosaur*** in 1842,
  - dinosaurs have been the objects of intense curiosity
- No other group of animals
  - has so thoroughly captured the public imagination,
  - but dinosaurs were only one type of Mesozoic reptile

Dinosaur Size and Diversity



The Age of Reptiles

- Other Mesozoic reptiles include
  - flying reptiles
  - marine reptiles,
  - as well as turtles, crocodiles, lizards, and snakes
- Geologists informally call the Mesozoic
  - "The Age of Reptiles,"
  - calling attention to the importance of reptiles
  - among land-dwelling animals

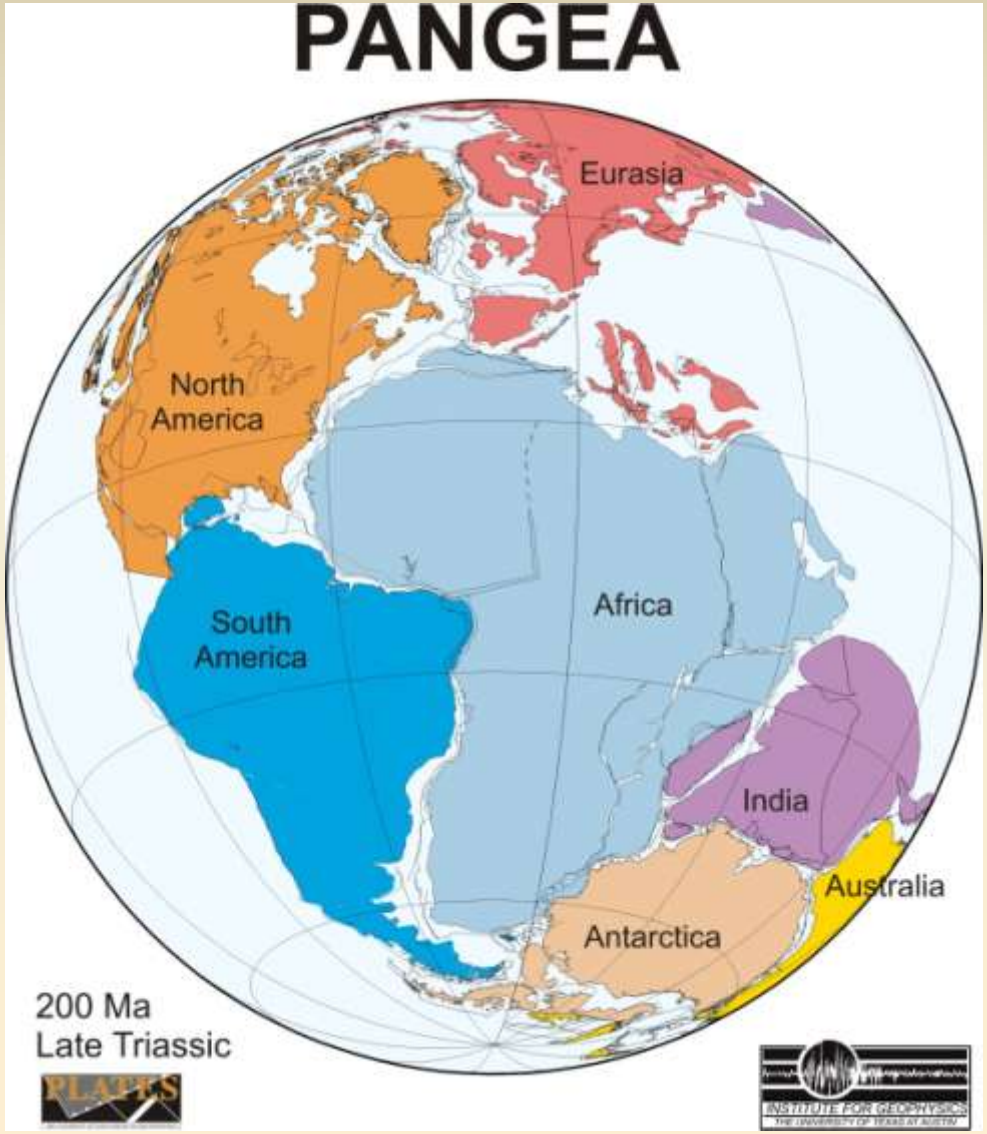
Mammals Too

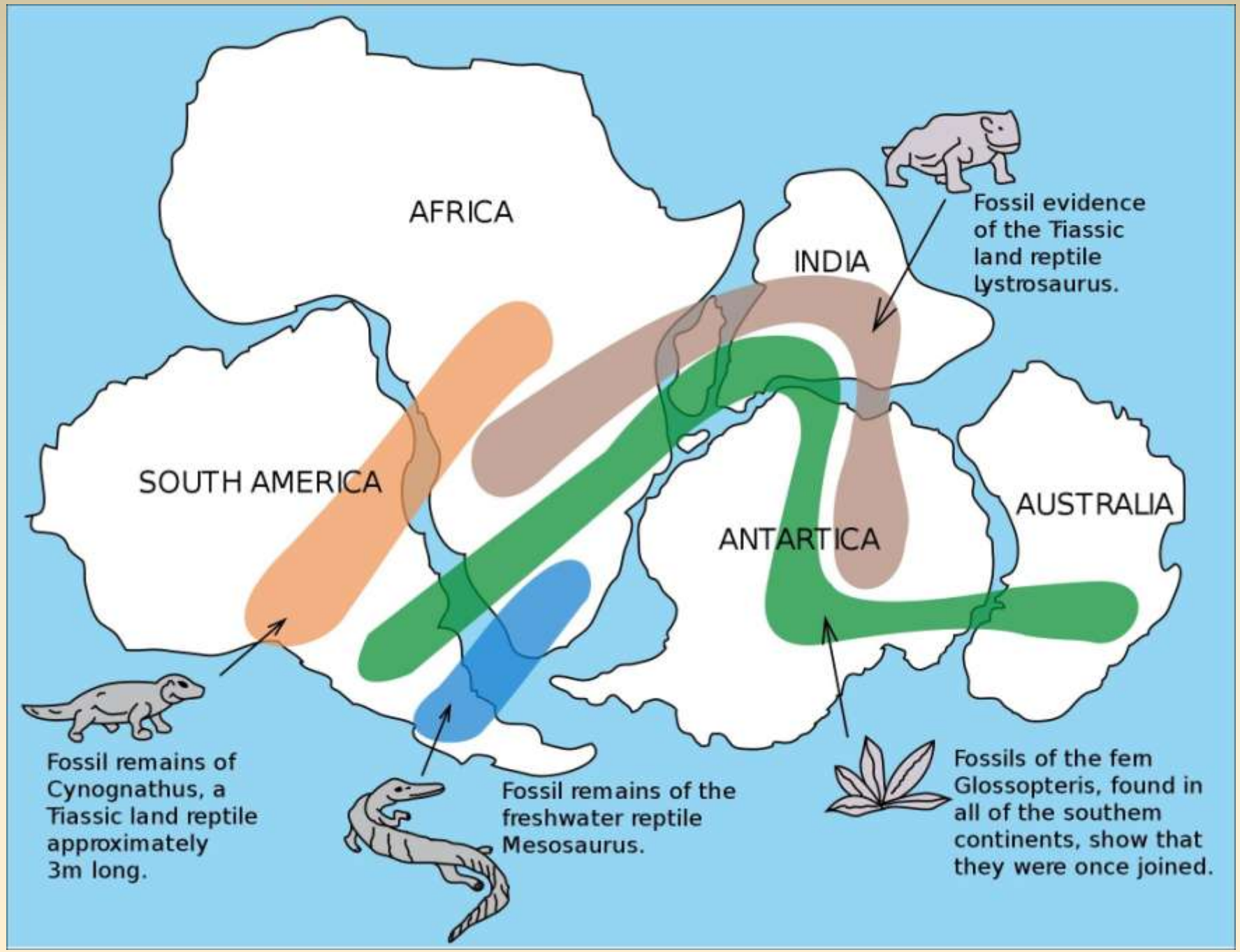
- Mammals and dinosaurs were contemporaries
  - throughout the Mesozoic,
  - but mammals were not particularly diverse
  - and none were very large

Birds

- Birds also made their appearance,
  - most likely evolving from small carnivorous dinosaurs during the Jurassic
- Remarkable discoveries of feathered dinosaurs in China
  - have important implications about dinosaur biology
  - and are important for evaluating dinosaur relationships with birds

Key theme: Pangea breaks up

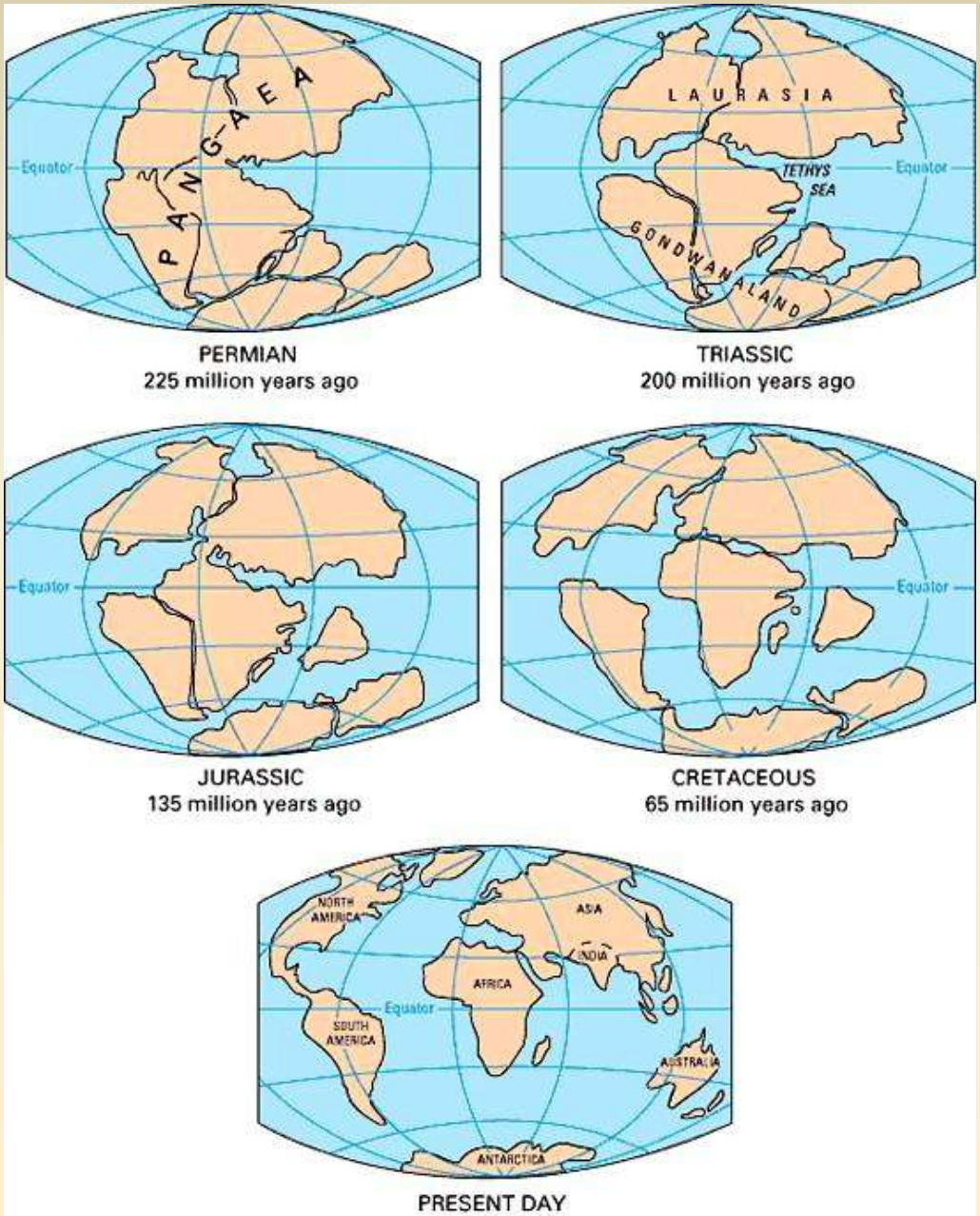



AFRICA
INDIA
Fossil evidence of the Tiassic land reptile lystrosaurus.
SOUTH AMERICA
AUSTRALIA
ANTARTICA
Fossil remains of Cynognathus, a Tiassic land reptile approximately 3m long.
Fossil remains of the freshwater reptile Mesosaurus.
Fossils of the fem Glossopteris, found in all of the southem continents, show that they were once joined.

Key theme: Pangea breaks up

Pangea – 250 million years ago

Key theme: Pangea breaks up

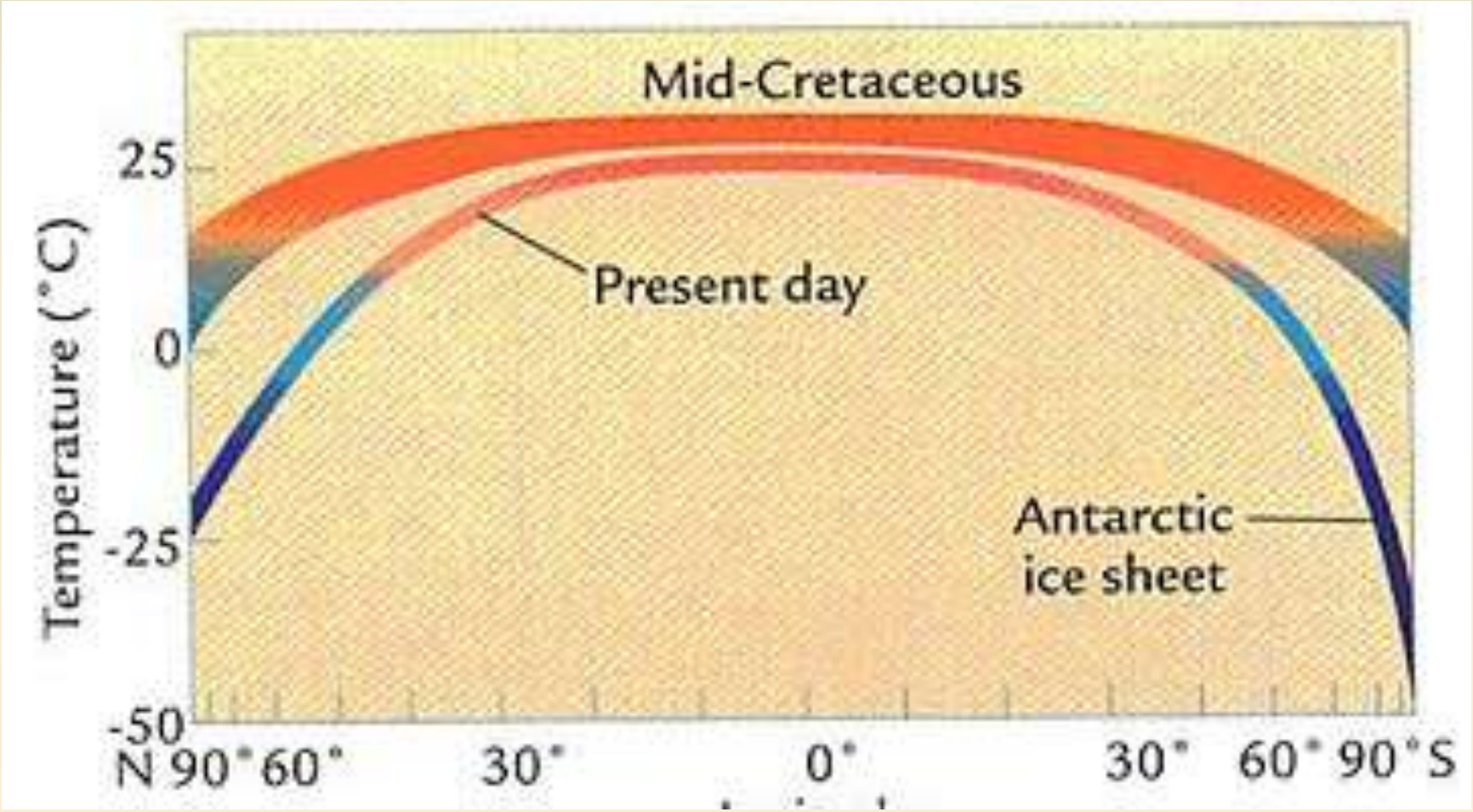


- Process will take 150 my and will extend into the Cenozoic
- Laurentia/Baltica and Australia/Antarctica are still joined at the end of the Mesozoic

Geographic Distribution Of Life Through Mesozoic

- Pangea existed as a large landmass through Triassic. Climate was relatively similar over a wide latitude range. These factors allowed for wide distributions of species over many different continents
- South America/Antarctica/Australia became island continents in Late Mesozoic
  - Faunas on these continents began to develop independently of other continents
  - Marsupials remained the dominant mammals in both South America and Australia
  - Laurasian continents continued to have strong faunal interchanges until Cenozoic

Key point: warm climate is the driver of biodiversity/distribution in Mesozoic



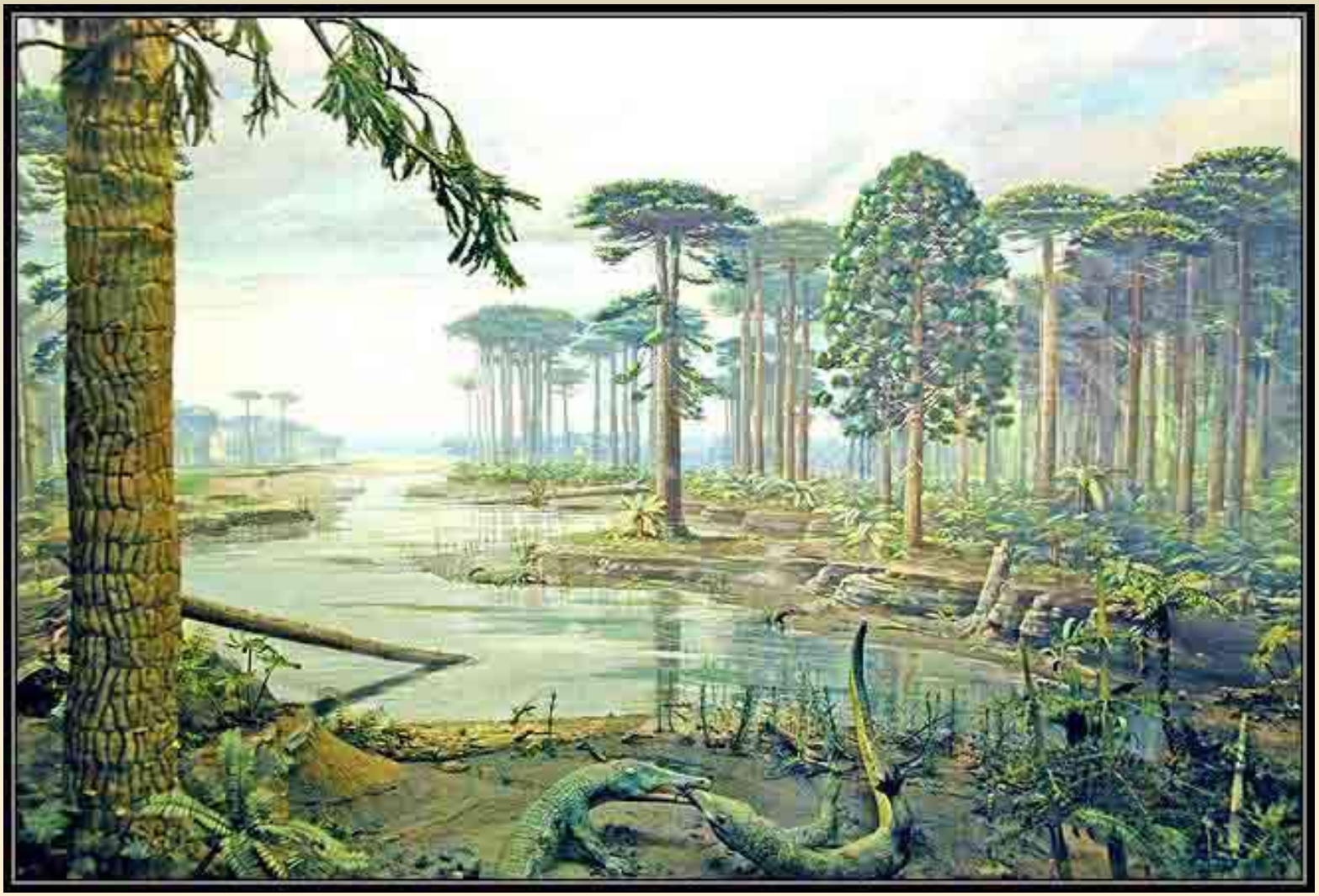
Triassic

Lystrosaurus - by far the most common terrestrial vertebrate of the Early Triassic

Lystrosaurus: had only two teeth, a pair of tusk-like canines and is thought to have had a horny beak that was used for biting off pieces of vegetation. It was a heavily-built, herbivorous animal, approximately the size of a pig .

Triassic Landscape

Triassic plants were mainly seed plants - conifers and cycads. The Triassic also saw the development of forked-frond seed ferns.



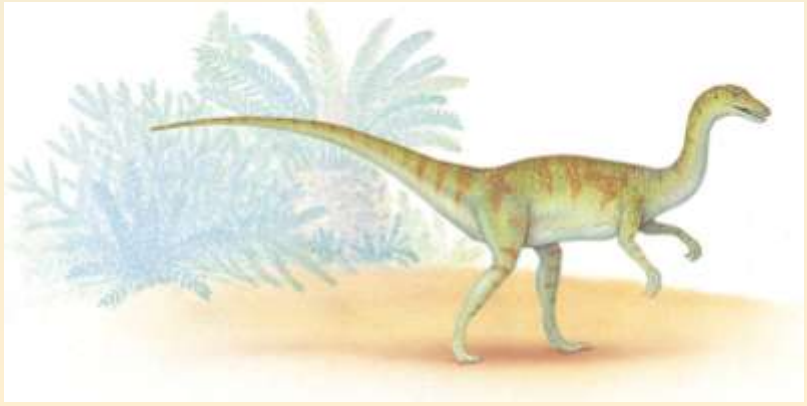
Triassic Araucariad Forest
From Petrified Forest National Park Museum

Dinosaurs

- **Dinosaurs appeared in the Late Triassic**, about 225 MY ago.
- The name "dinosaur" comes from the Greek *deinos* = "terrifying" and *sauros* = "lizard".
- The earliest dinosaurs were small. Many were less than 3 ft long.
- By the end of the Triassic, dinosaurs were up to 20 feet long.
- They became much larger later in the Jurassic and Cretaceous.

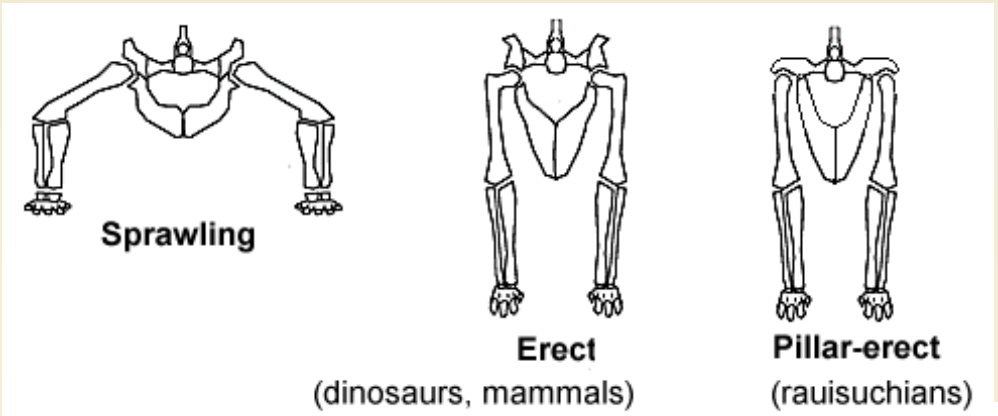
Basal Archosaurs

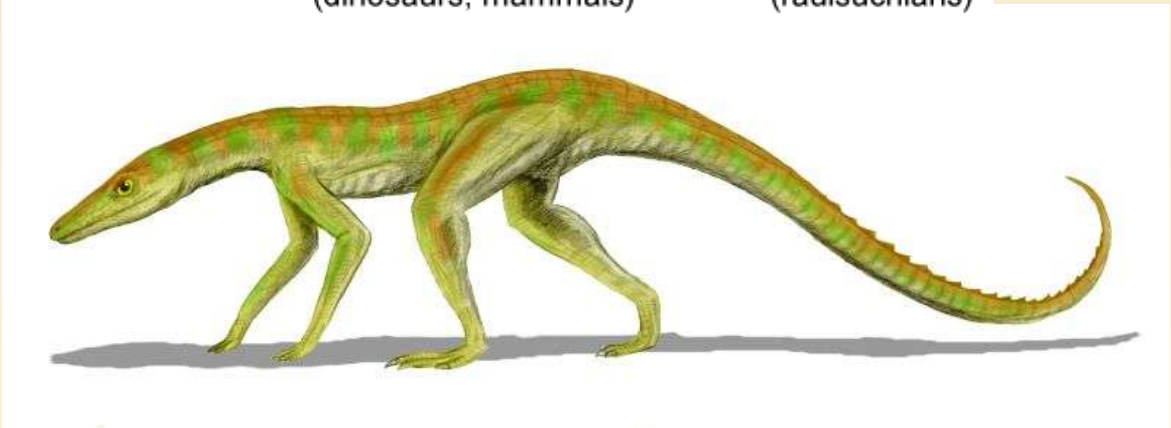
- Basal archosaurs (formerly called thecodonts) were small, agile reptiles with long tails and short fore-limbs.
- Many were bipedal (walked on 2 legs). This freed their fore-limbs for other tasks such as catching prey, and later, flight.



Hesperosuchus

Dinosaur Locomotion





Triassic Dinosaurs

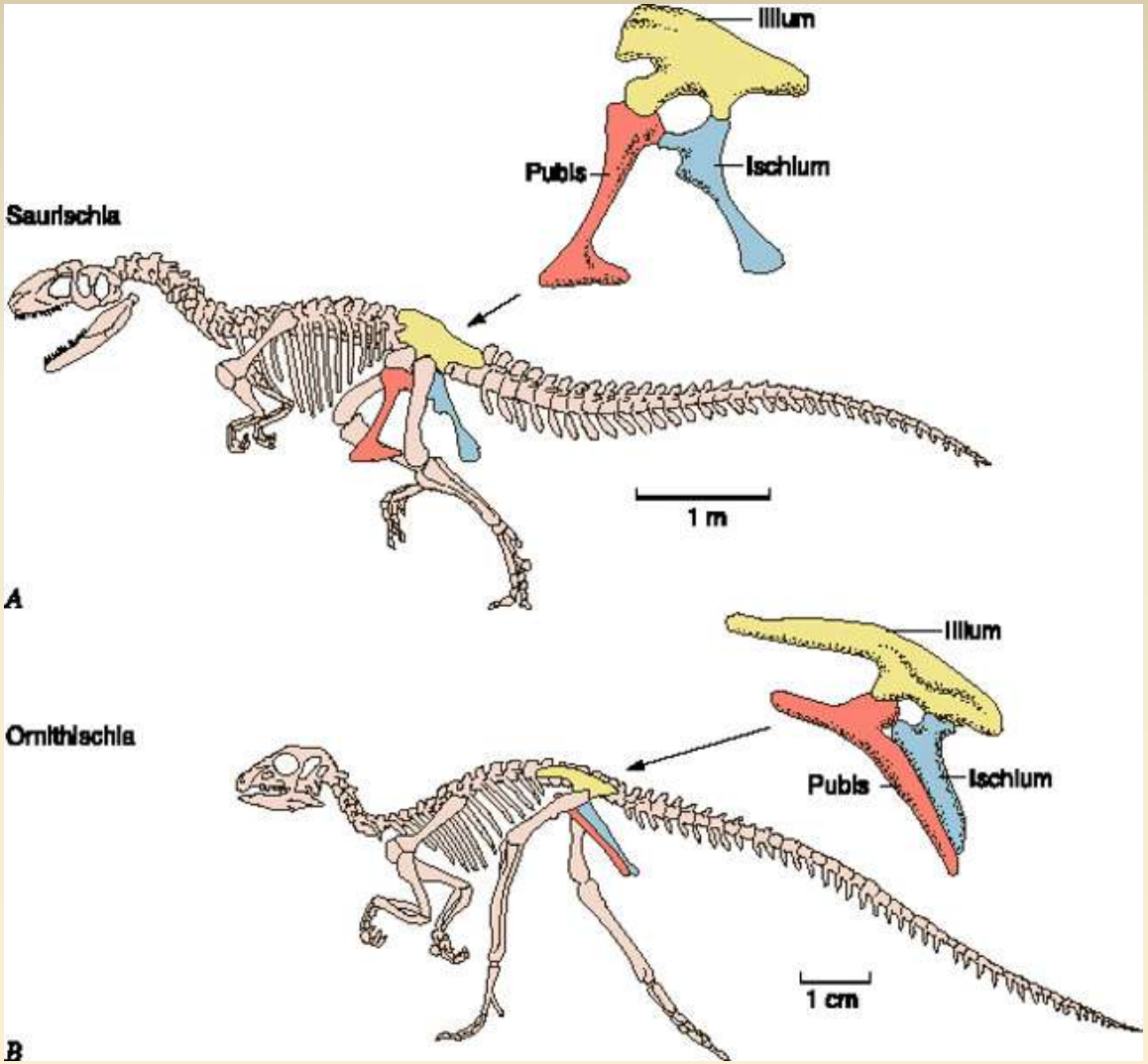
Dinosaurs

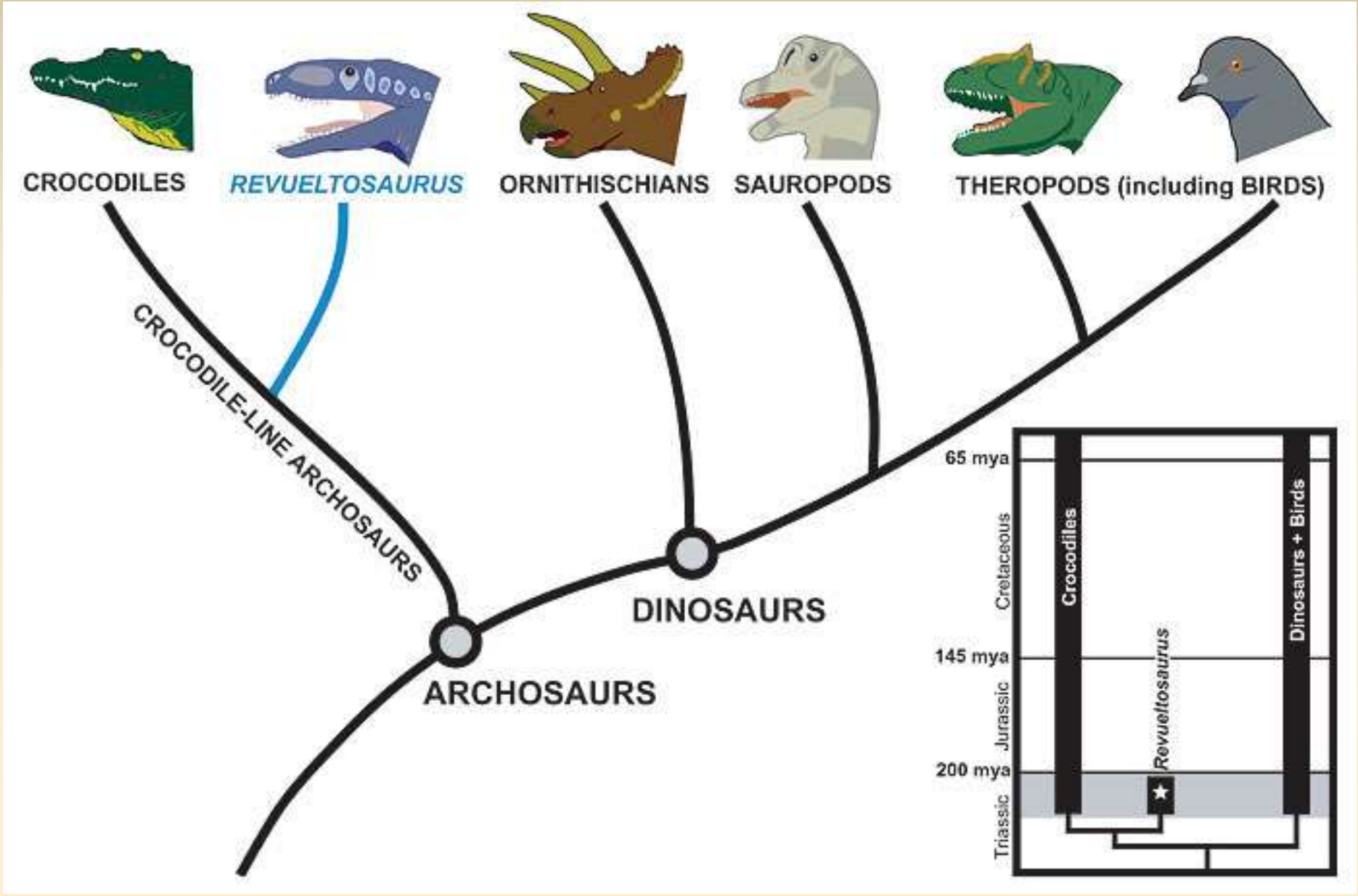
- Dinosaurs were composed of two orders: Saurischia (lizard-hipped) and Ornithischia (bird-hipped)
  - **Saurischia**: pelvic bones like thecodonts
  - **Ornithischia**: pubis parallel to ischium like birds
  - Earliest dinosaurs: saurischia (Triassic, 225 m.y. old, Argentina)

Dinosaurs

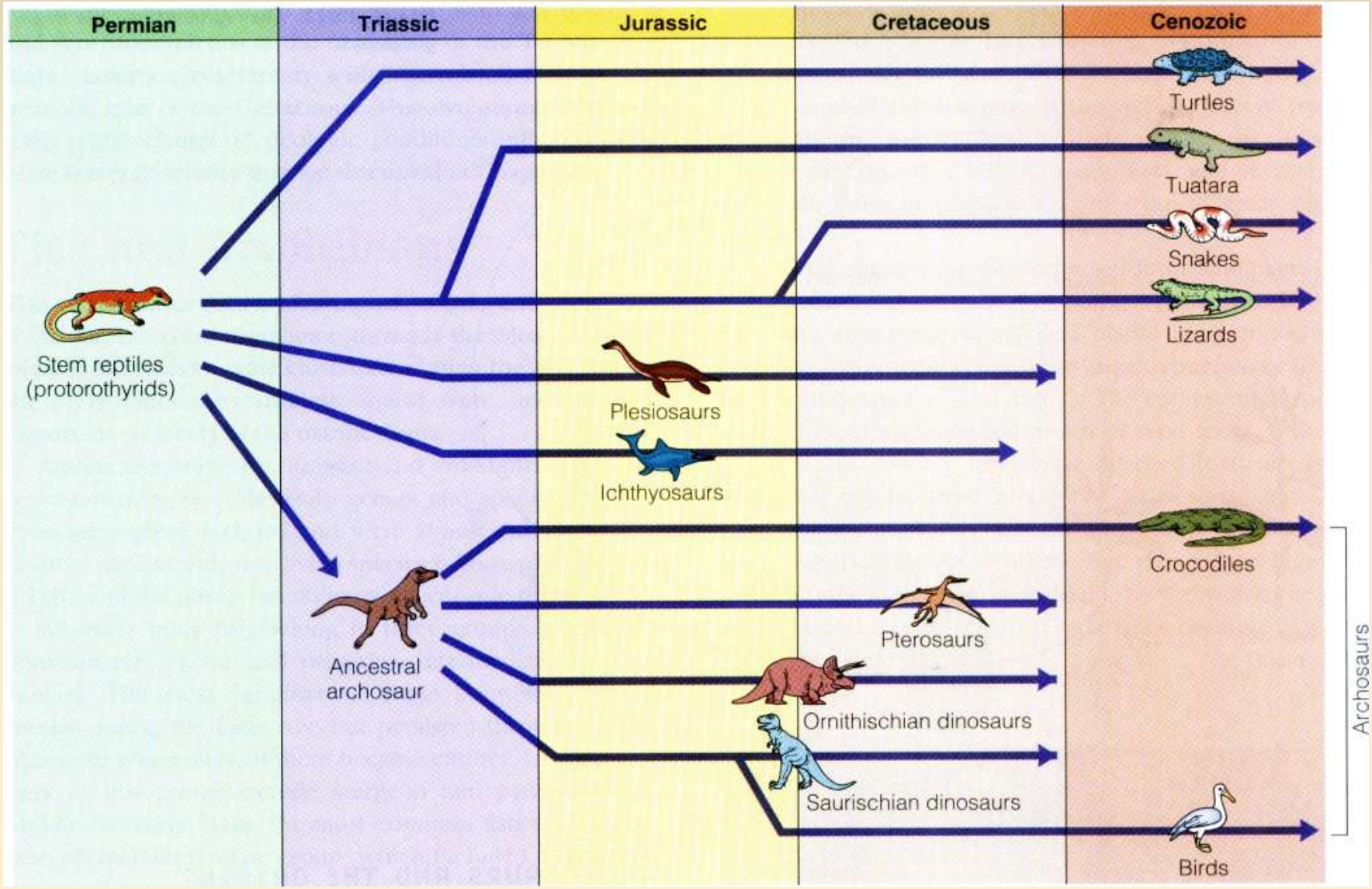
- Saurischian dinosaurs - lizard-hipped

- Ornithischian dinosaurs - bird-hipped

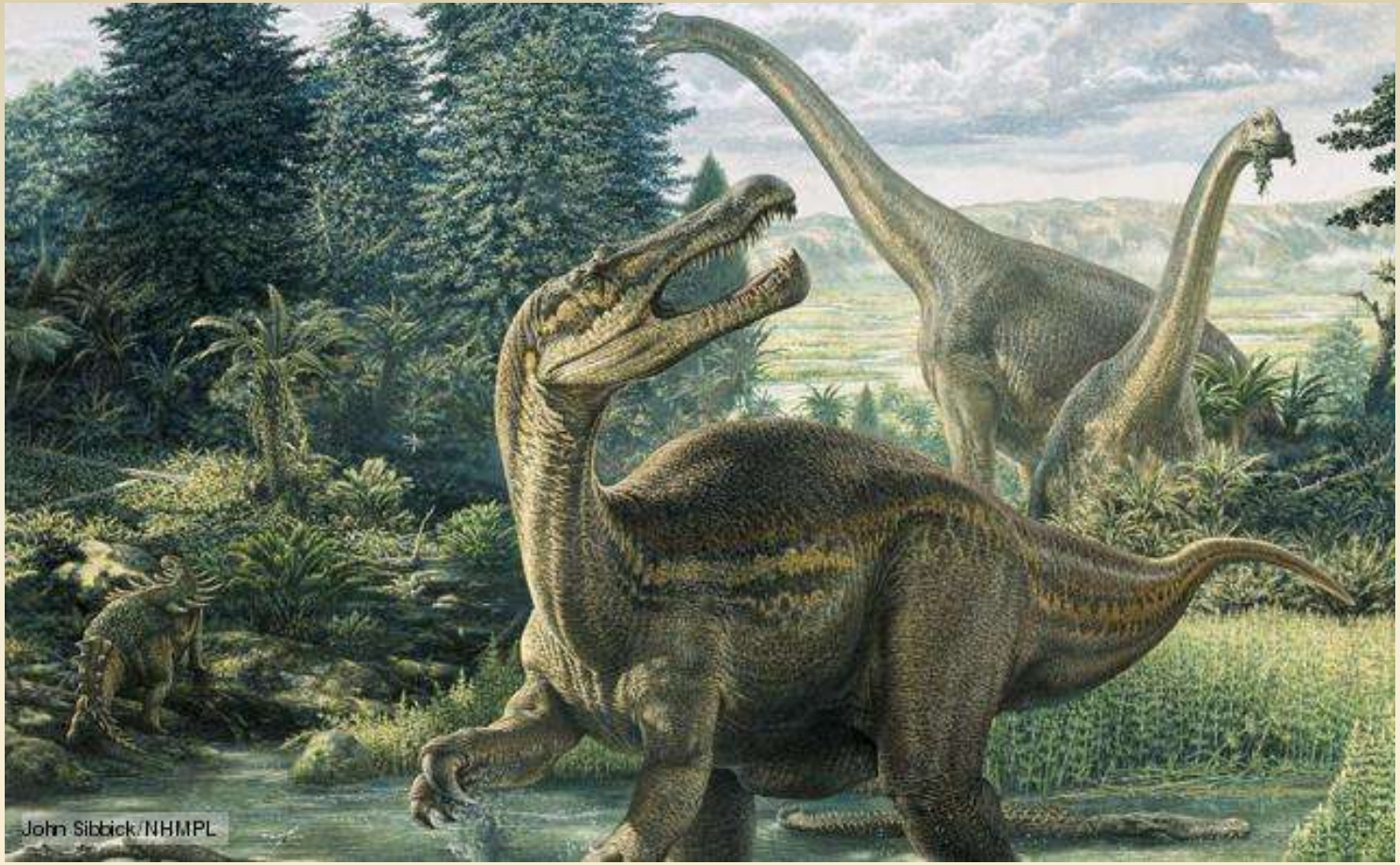



CROCODILES
REVUELTOSAURUS
ORNITHISCHIANS
SAUROPODS
THEROPODS (including BIRDS)
CROCODILE-LINE ARCHOSAURS
DINOSAURS
ARCHOSAURS
65 mya
145 mya
200 mya
Cretaceous
Jurassic
Triassic
Crocodiles
Revueltosaurus
Dinosaurs + Birds

Relationships among fossil and living reptiles and birds



Saurischia - Lizard-hipped dinosaurs

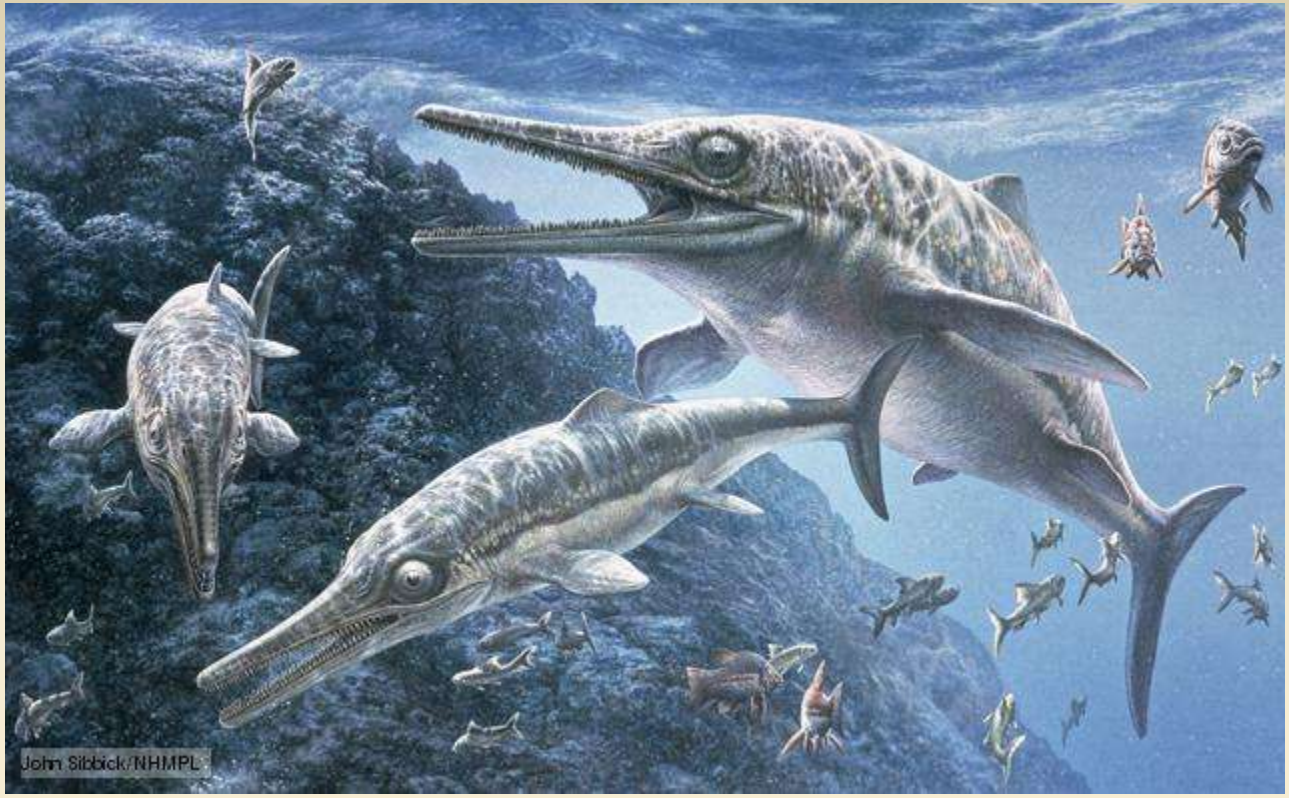


The earliest known dinosaurs, lizard-hipped dinosaurs first appeared in the mid Triassic. As well as these first dinosaurs, the order includes **all the carnivorous dinosaurs and one group of herbivores - the sauropods** and their close relatives

Ornithischia - Bird-hipped dinosaurs

Derive their name from the shape of their pelvis, which resembles that of modern birds, whose pubis points to the rear of the animal. Also had a horny beak, which they used to crop plants. **Duck-billed dinosaurs, horned dinosaurs and armored dinosaurs** were all of the bird-hipped variety.

Ichthyosaurs

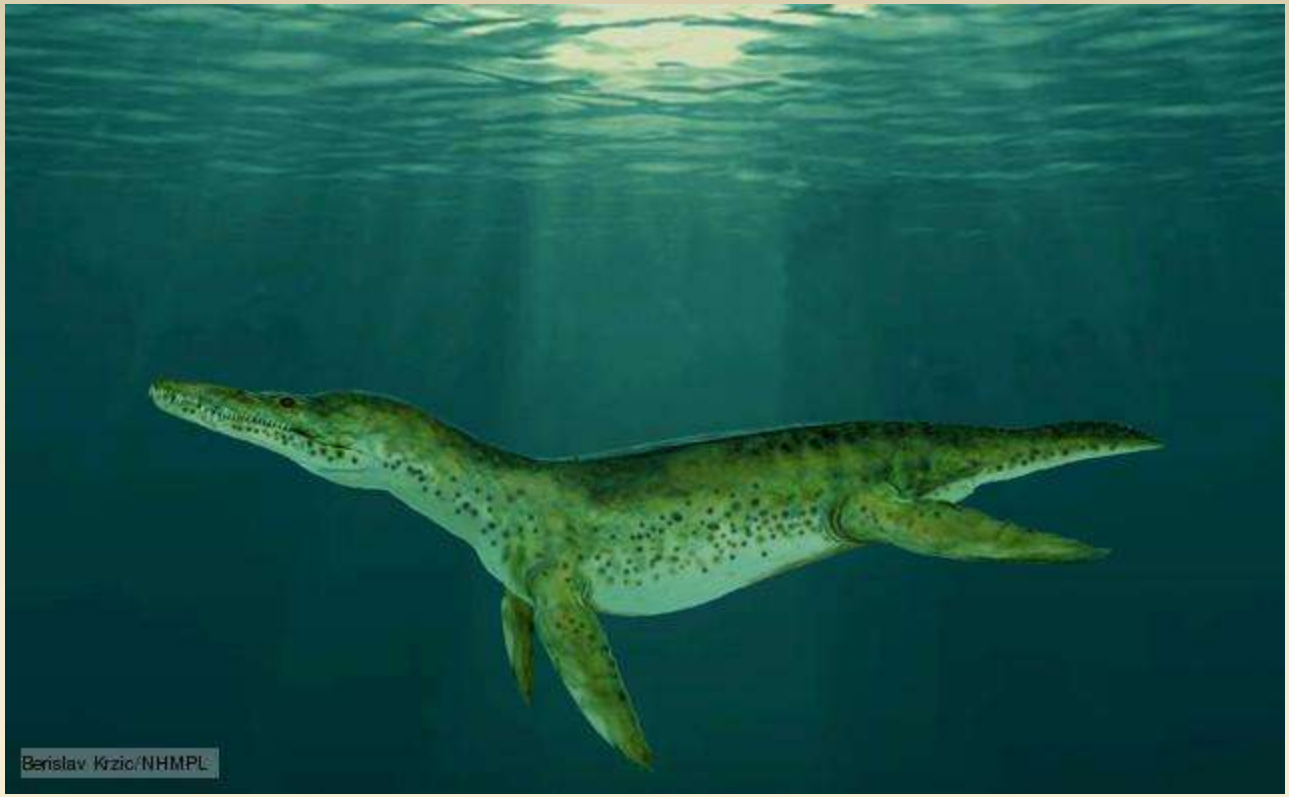


Predatory marine reptiles that swam the world's oceans while dinosaurs walked the land. They appeared in the Triassic period, dying out around 25 million years before the extinction event that wiped out the dinosaurs.

Plesiosauria

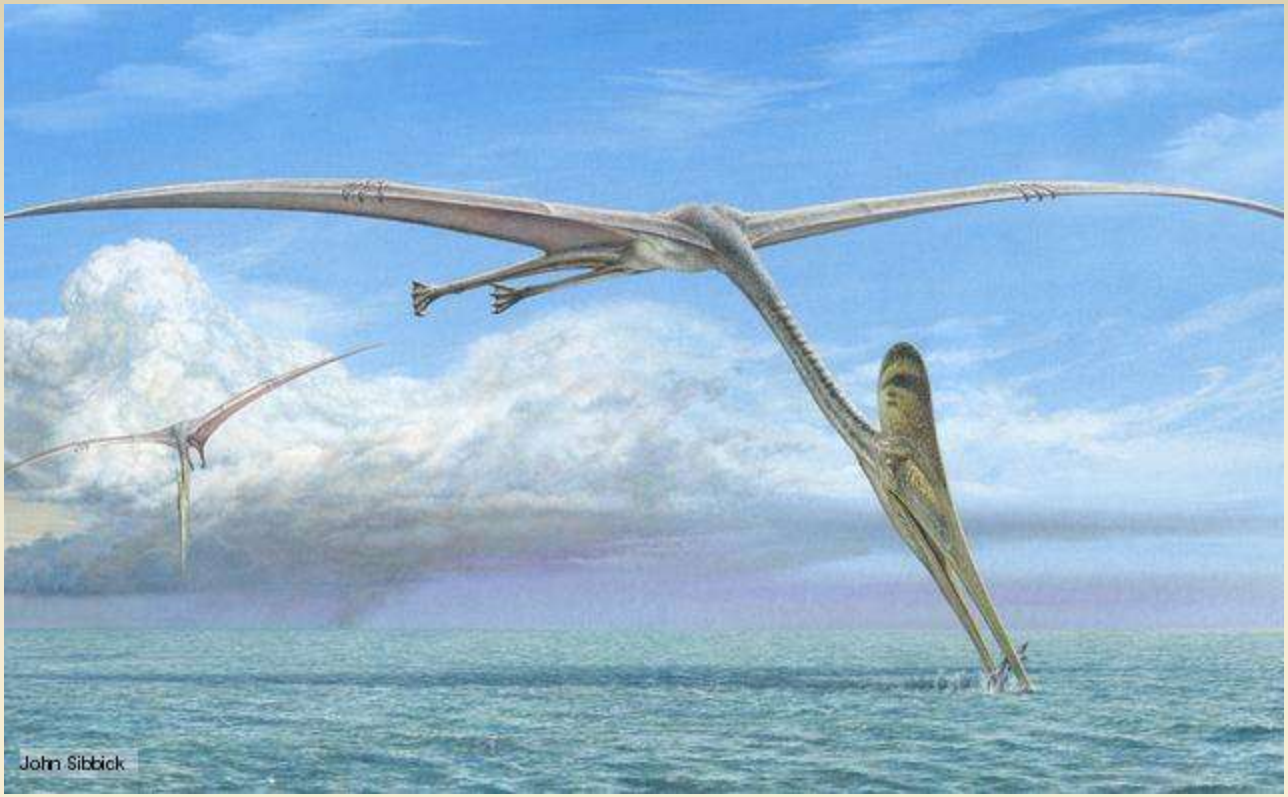
Includes the large, carnivorous, marine reptiles the Plesiosaurs and Pliosaurs. They used their flippers to propel themselves through the water, rather like a turtle except that they used both the front and rear flippers.

Pliosaurs



Short-necked plesiosaur: marine reptiles built for speed compared to their long-necked cousins. Could swim at a little under 10 km/h. They were predators that hunted fish, cephalopod molluscs and other marine reptiles.

Pterosaurs - Pterodactyls

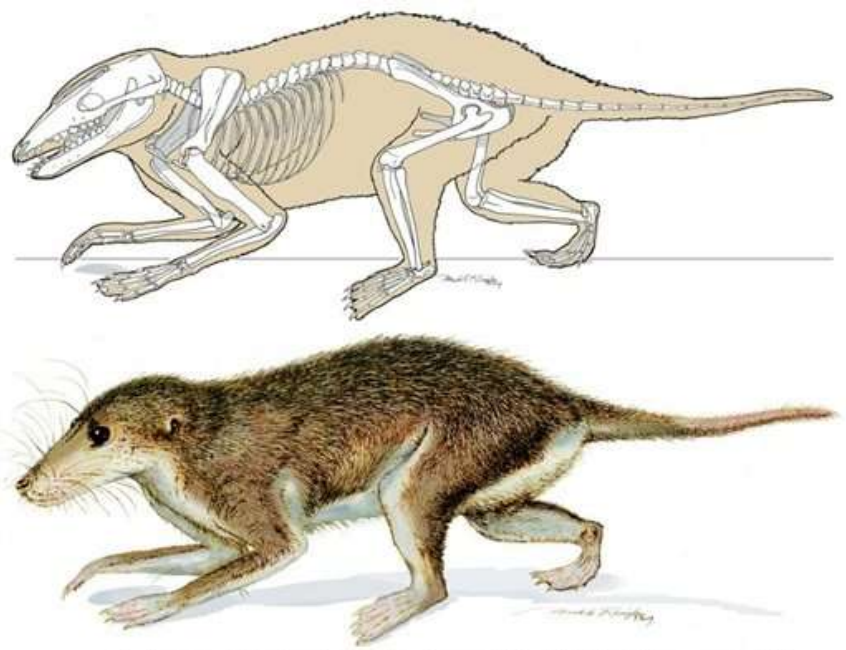


Winged reptiles - the first vertebrates to evolve powered flight. The evidence for flight comes from their light hollow bones, large brains and an extremely long fourth digit providing wing support.

Mammals

- Mammals evolved from mammal-like reptiles in the Late Triassic. Early mammals were rodent-like, and remained small throughout Mesozoic (smaller than housecats).
- Among the earliest mammals were **Megazostrodon**, **Eozostrodon**, and **Morganucodon**

True mammals appear in the Triassic

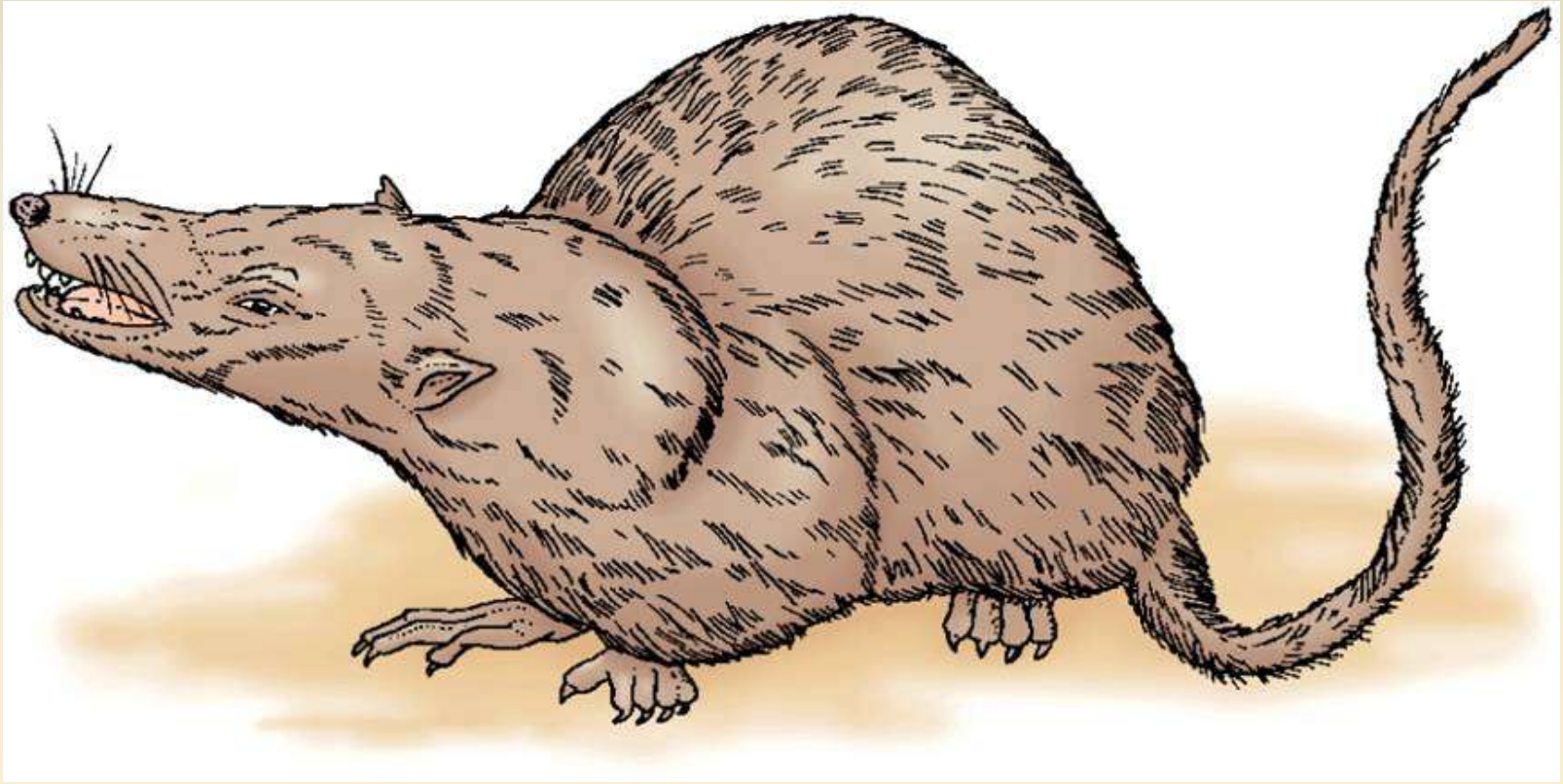


Cretaceous Mammal *Maotherium asiaticus* (123 million years old)

Top: Skeletal Restoration of *Maotherium* as a terrestrial mammal
(Skeleton Reconstruction Illustration: Mark A. Klingler / Carnegie Museum of Natural History)
Bottom: Restoration of *Maotherium asiaticus*
(Life Reconstruction Illustration: Mark A. Klingler / Carnegie Museum of Natural History)

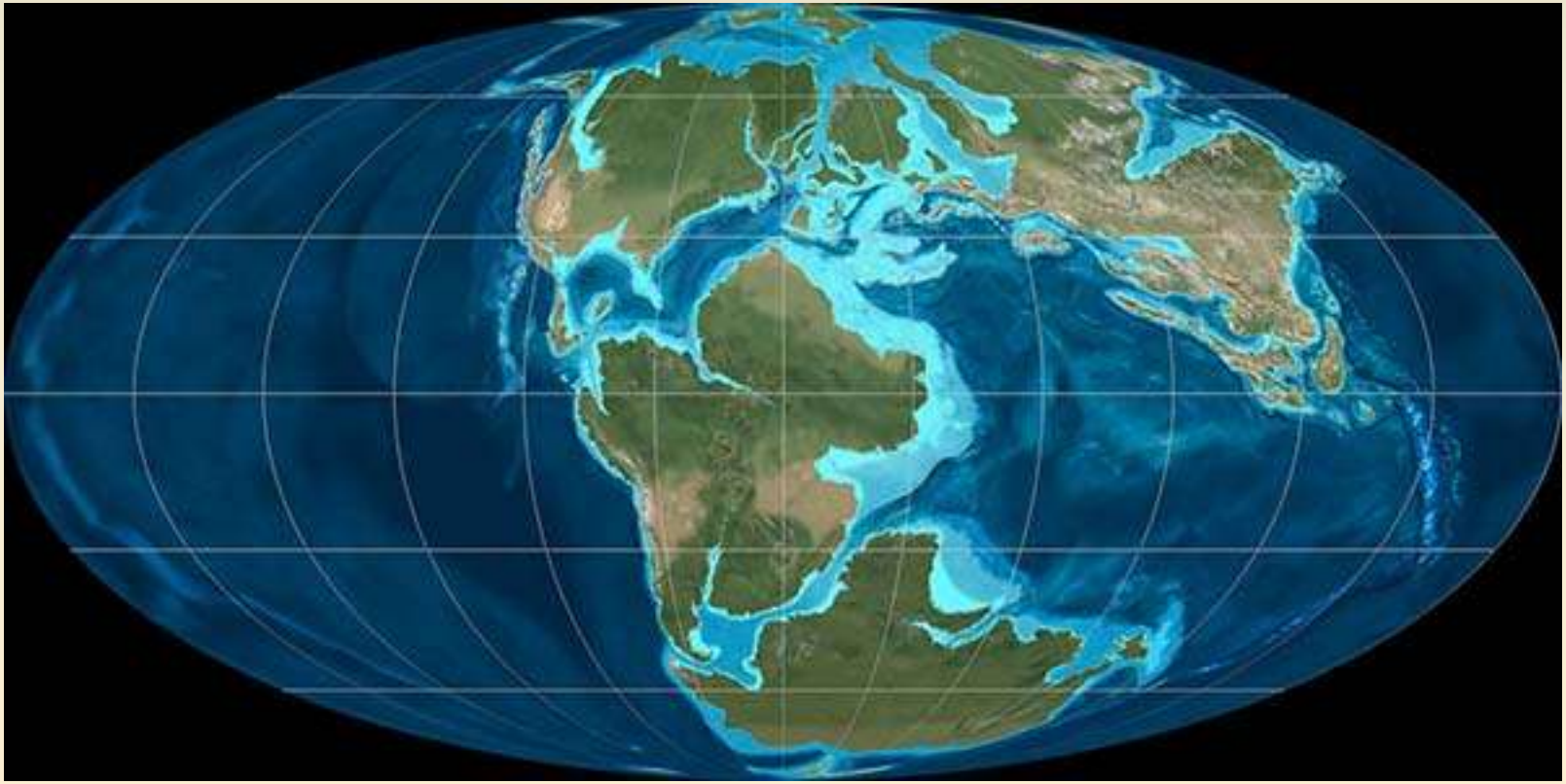
- Evolved from a lineage of mammal-like reptiles
- Hair, mammary glands homeostasis (= “warm-blooded”, though some of the dinosaurs may have been)

Restoration of *Morganucodon*, an early mammal from the Late Triassic of Wales.

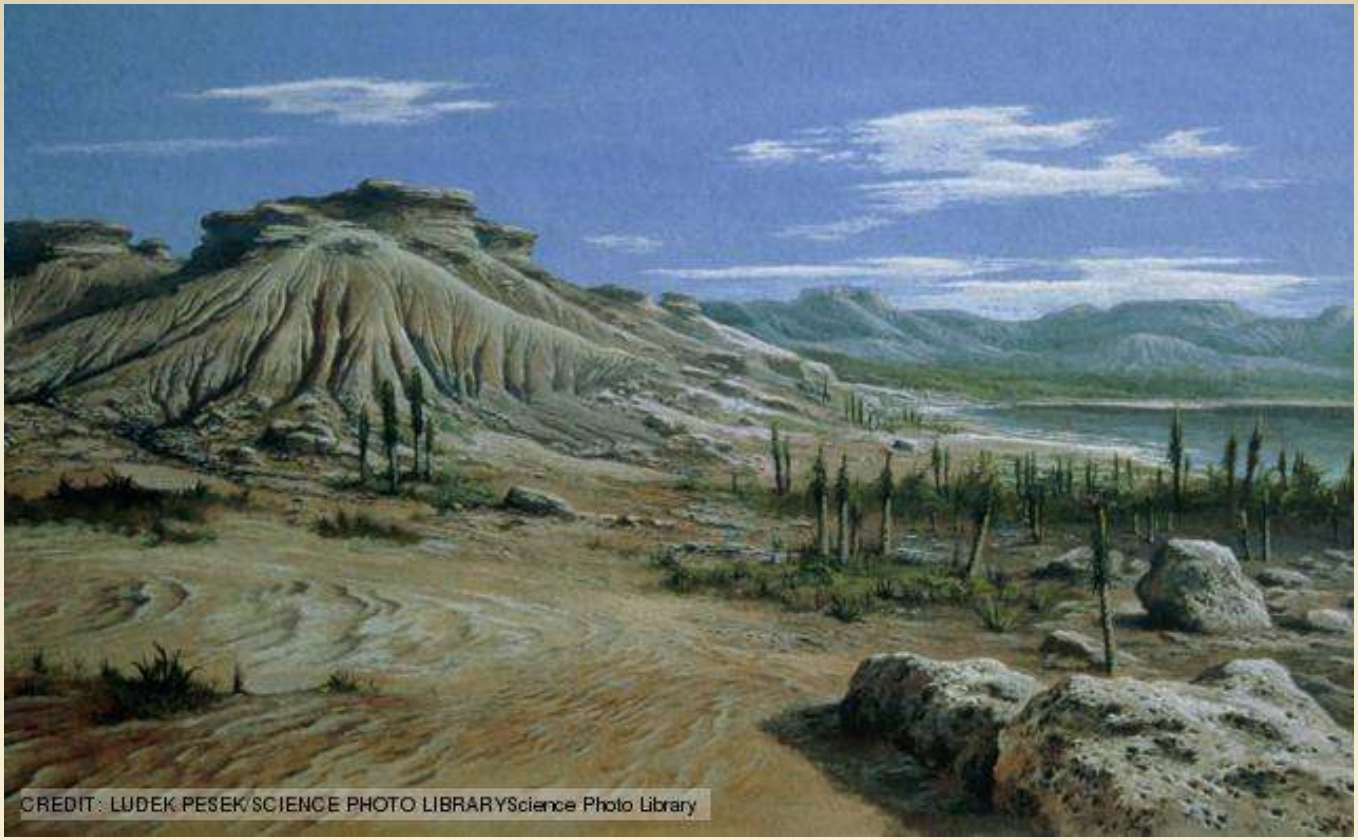


Late Jurassic

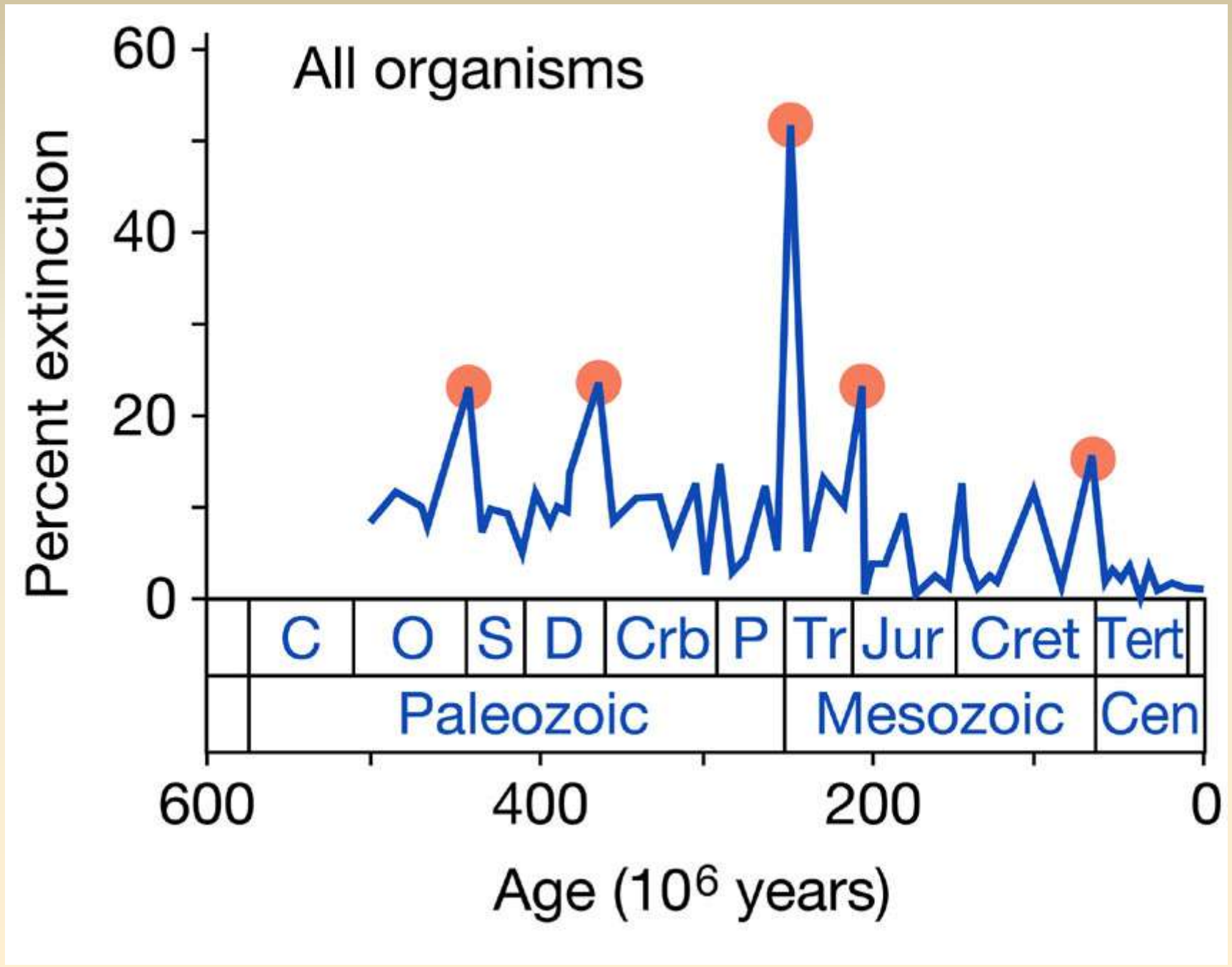
Pangea split into two, northern Laurasia and southern Gondwanaland



Triassic-Jurassic mass extinction



During the final 18 million years of the Triassic period, there were two or three phases of extinction whose combined effects created the Triassic-Jurassic mass extinction event. Climate change, flood basalt eruptions and an asteroid impact have all been blamed for this loss of life


All organisms
Percent extinction
60
40
20
0
C
O
S
D
Crb
P
Tr
Jur
Cret
Tert
Paleozoic
Mesozoic
Cen
600
400
200
0
Age (10⁶ years)

Triassic Extinction

- Hit mammals hard
- Dinosaurs not as affected
- Poorly understood, sediments unavailable.
- Possible causes:
  - Falling sea levels, warm shallow seas decreased, reefs died
  - Pangaea fragmentation lead to volcanic CO_2 release
  - the start of a volcanic rift forming between the Americas and Africa and Europe. Very large eruptions occurred along the rift zone (known as the Central Atlantic Magmatic Province) for about 500,000 years.

What went extinct?

22% of all marine families, 53% of all genera, an estimated **76-84% of all species**.

Most mammal-like reptiles and large amphibians disappeared, as well as **many dinosaur groups**.

In the sea, the largest entire group to die out was the **strange eel-like conodonts**.

Reef ecosystems were decimated again.

Ammonites, brachiopods and bivalves were also badly affected, with the latter losing over 90% of its species.

Thrinaxodon

Mammal-like reptiles such as *Thrinaxodon*, which lived about 251 million years ago, thrived in the Early Triassic. But the next mass extinction at the end of the Triassic resulted in the group's demise.

Jurassic

Jurassic Forests – Cycads, Conifers, Pinales

Jurassic lands were generally greener and more lush than they had been in Triassic times, and vegetation types were more uniform the world over.

Cycads – gymnosperm seed plants

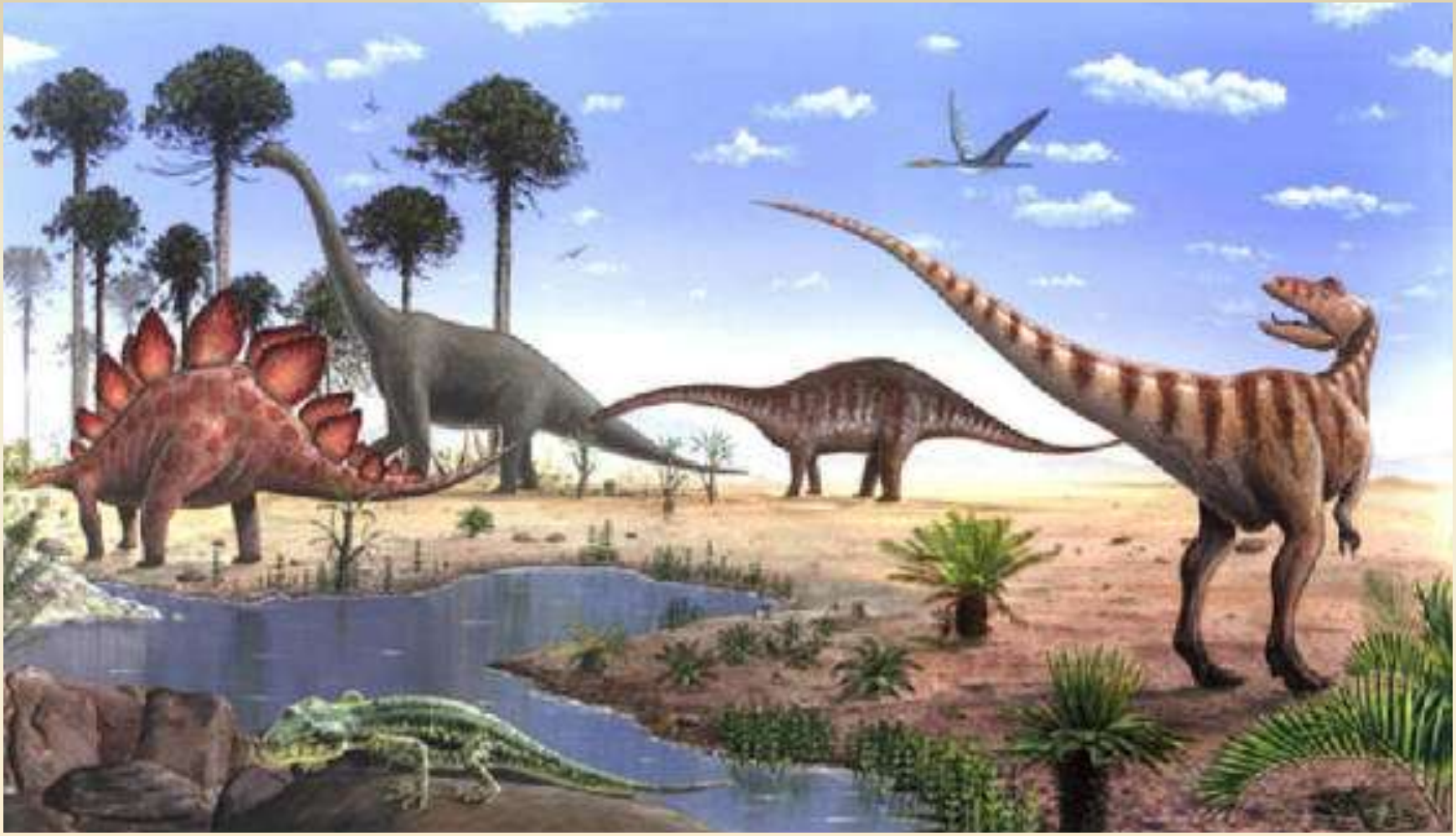
Gymnosperm Forests - Conifers - Pinales

The Conifers in particular dominated the flora, as during the Triassic; they were the most diverse group and constituted the majority of large trees.

Jurassic Gymnosperm Conifer Forests

Painting of a late Jurassic Scene on one of the large island in the Lower Saxony basin in northern Germany. It shows an adult and a juvenile specimen of the sauropod *Europasaurus holgeri* and iguanodons passing by. There are two *Compsognathus* in the foreground and an *Archaeopteryx* at the right.

Jurassic Dinosaurs

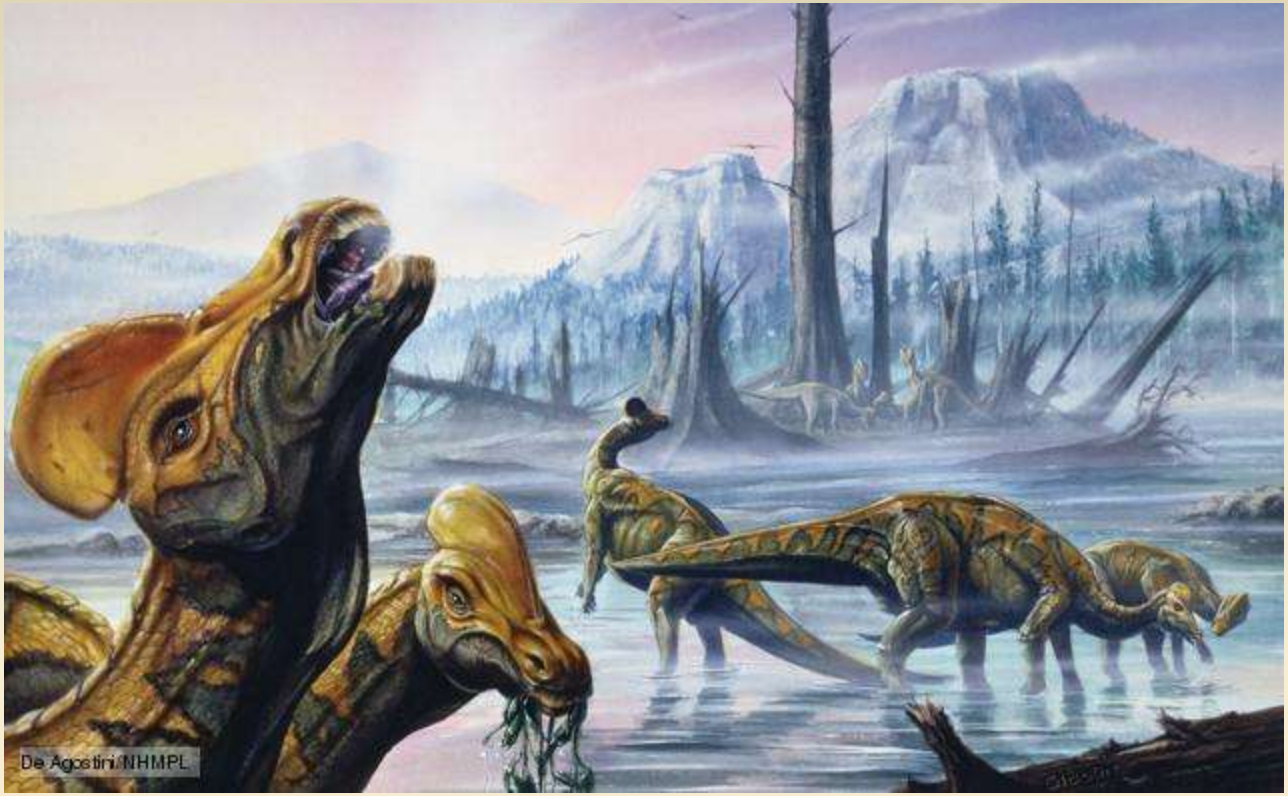


Armored Dinosaurs

Stegosaurus

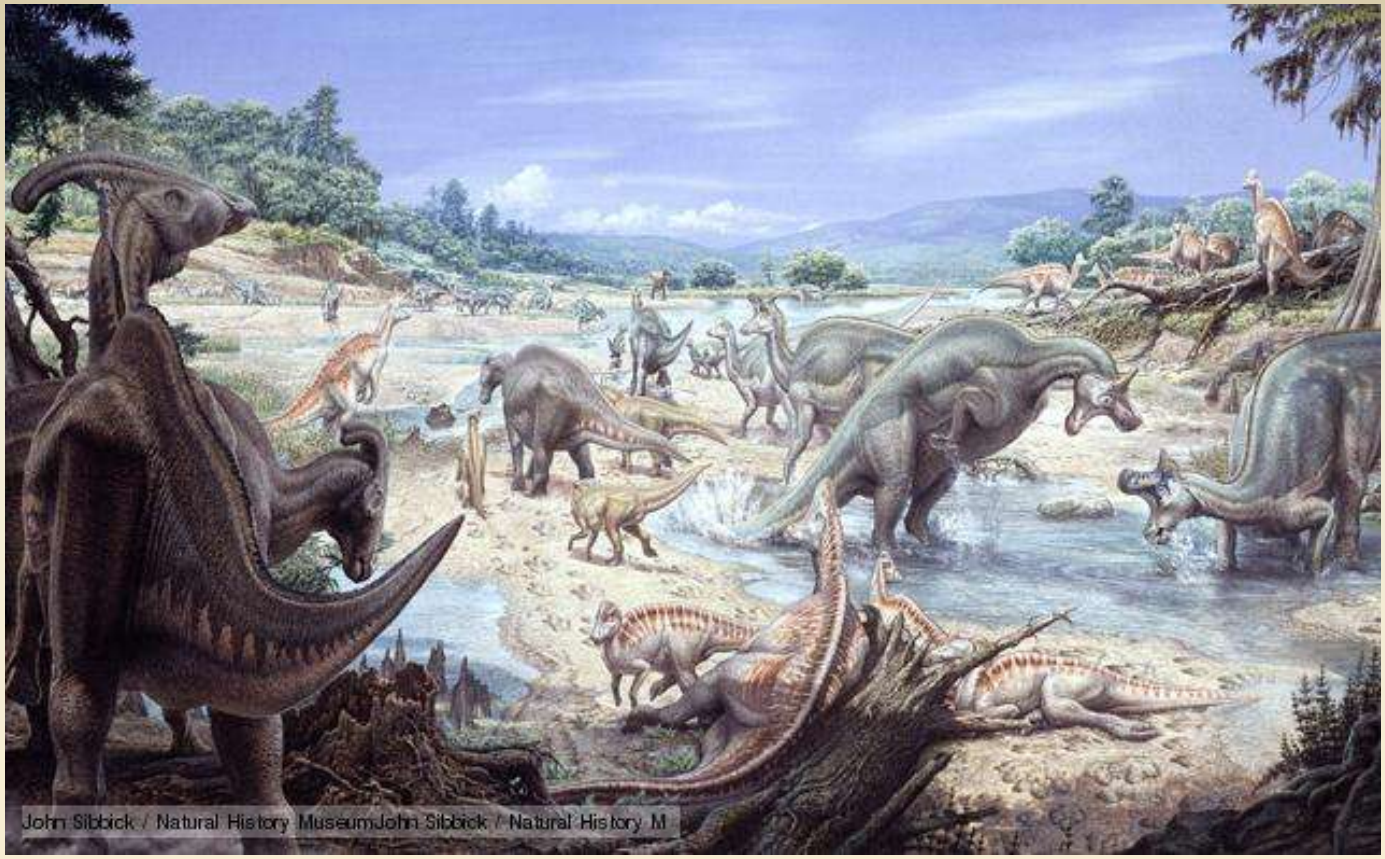
About the size of a bus. Distinctive and heavily built, they were herbivores with short forelimbs and would have walked with their small head close to the ground and the four-spiked tail held high. The double row of plates running along the back helped control body temperature and were probably used in display or possibly in defence

Ceropod dinosaurs



All plant-eaters and include the horned and duck-billed dinosaurs. The secret of their success was in their teeth. These were much more efficient at grinding up plant food than your typical dinosaur's dentition

Ornithopod dinosaurs



Most advanced chewing apparatus ever developed by a reptile, ornithopod dinosaurs became a most successful group of herbivorous dinosaurs. They rapidly became a prominent feature on North America's Cretaceous landscape. Notable ornithopods include the **duck-billed hadrosaurs and iguanodon**.

Sauropod dinosaurs

The largest sauropod dinosaurs weighed close to 100 tonnes - ten times the record weight of a modern elephant. Sauropods therefore include the largest land animals ever to have lived. They were a very successful herbivorous group, arising in the early Jurassic and surviving for around 100 million years

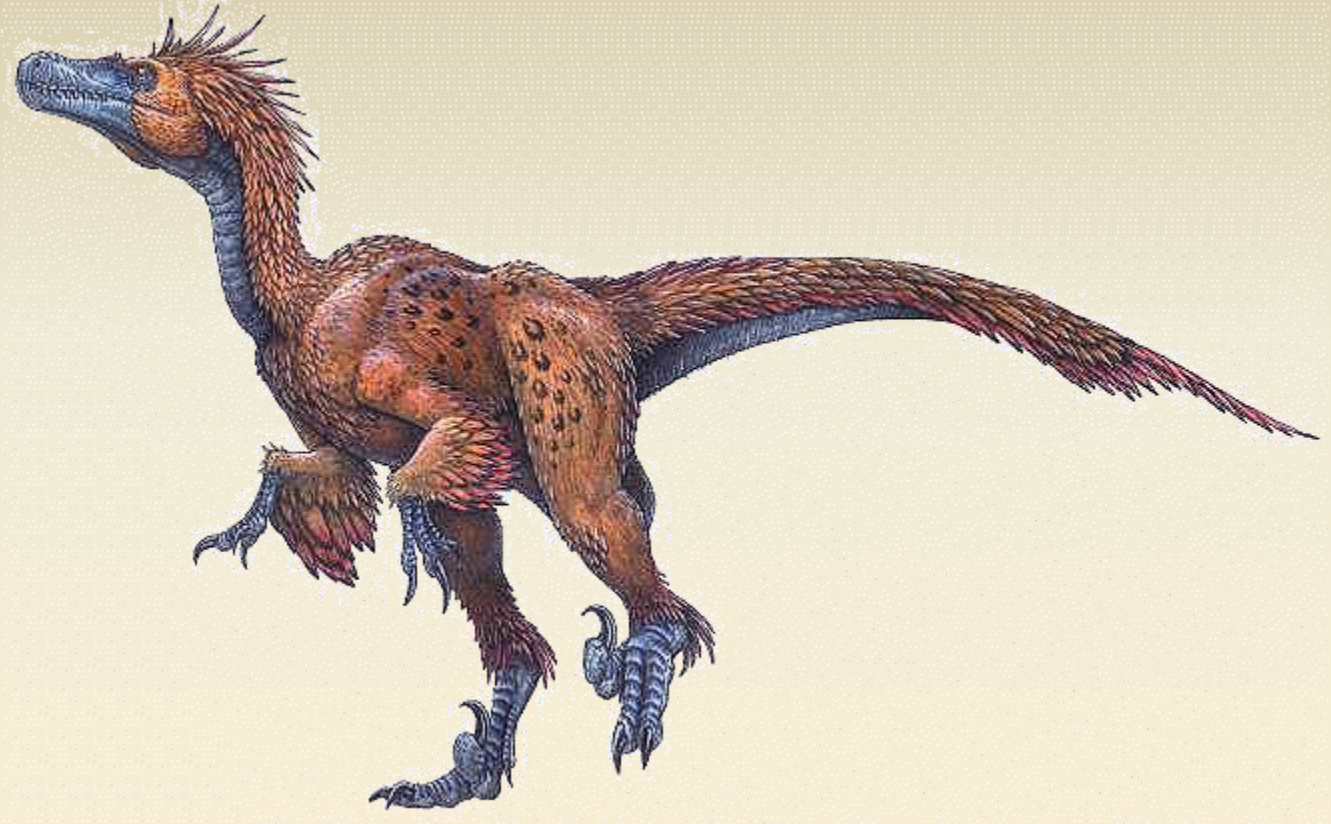
Apatosaurus (formerly Brontosaurus)

One of the larger sauropod dinosaurs, and therefore one of the largest animals ever to have walked the Earth. Peg-like teeth effectively stripped leaves from trees, but were no use for chewing, so Apatosaurus probably swallowed stones to grind up its meals in the gizzard.

Theropod dinosaurs

Top predators in the Jurassic and Cretaceous periods. For over 100 million years theropods were the only large carnivores on land and included all the infamous carnivorous dinosaurs - Tyrannosaurus, Velociraptor and Spinosaurus. However, not all theropods were predators.

Dromaeosaurs (raptors)



Carnivorous dinosaurs closely related to birds. Several fossils have been found with evidence of feathers, and many scientists believe that the whole group had an insulating covering of feathers. All dromaeosaurs have a large, sickle-shaped claw on each hind foot, which helped them climb.

Epidexipteryx

Epidexipteryx had four long ribbon-like display feathers on its tail, almost certainly used to attract a mate or threaten an enemy. This strongly suggests that feathers were used for ornamentation long before flight. Epidexipteryx lived between 152 and 168 million years ago, in the mid to late Jurassic Period

True birds appear in the Jurassic

- *Archaeopteryx* is the first recognized bird
- Most specimens are from the Solnhofen lagenstatten in Germany
- True feathers, wishbone
- However, this creature was descended from one clade of coelurosaurian theropods; a different clade is believed to be the lineage for birds

Archaeopteryx

Earliest known flying birds and only about the size of a modern day magpie. Living around 150 million years ago, *Archaeopteryx* had developed flying abilities that may have evolved from gliding out of trees or simply running along the ground. Missing link shares sharp teeth and a long bony tail with small theropod dinosaurs, and a wishbone and feathers with the birds

Archaeopteryx

BIRD (Archaeopteryx lithographica) cast replica
Jurassic
Archaeopteryx ("ancient wing") is the oldest known bird. It had asymmetrical feathers like modern birds. It also had a large tail and teeth similar to dinosaurs.

Archaeopteryx

public domain image by Nobu Tamura, via Wikipedia commons

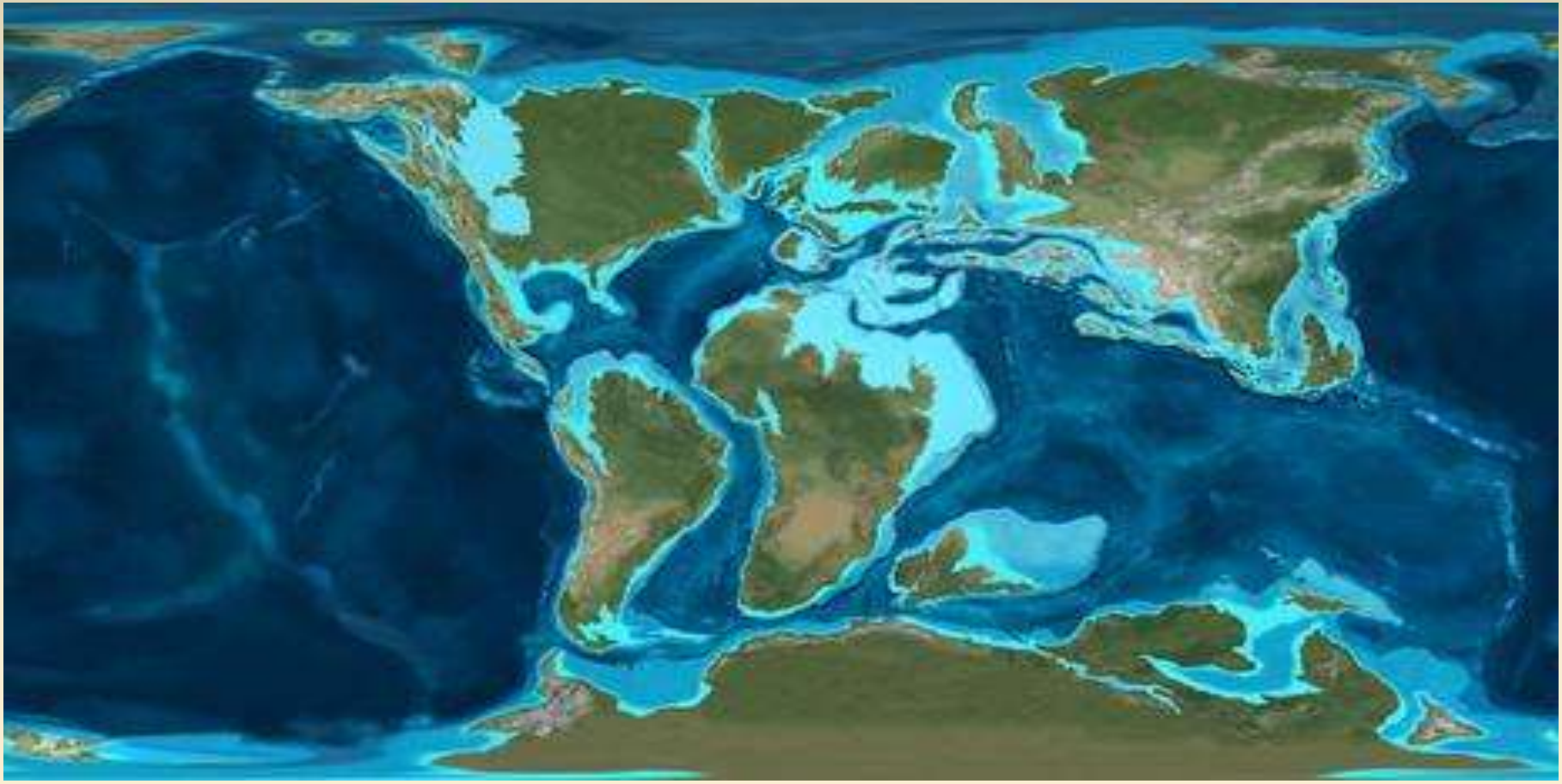
The life reconstruction is based on recent research identifying melanin in an outer feather of this fossil bird making it black. It is possible that other colors were also present in other feathers, so *Archeopteryx* may have been more colorful than this interpretation.

Cretaceous

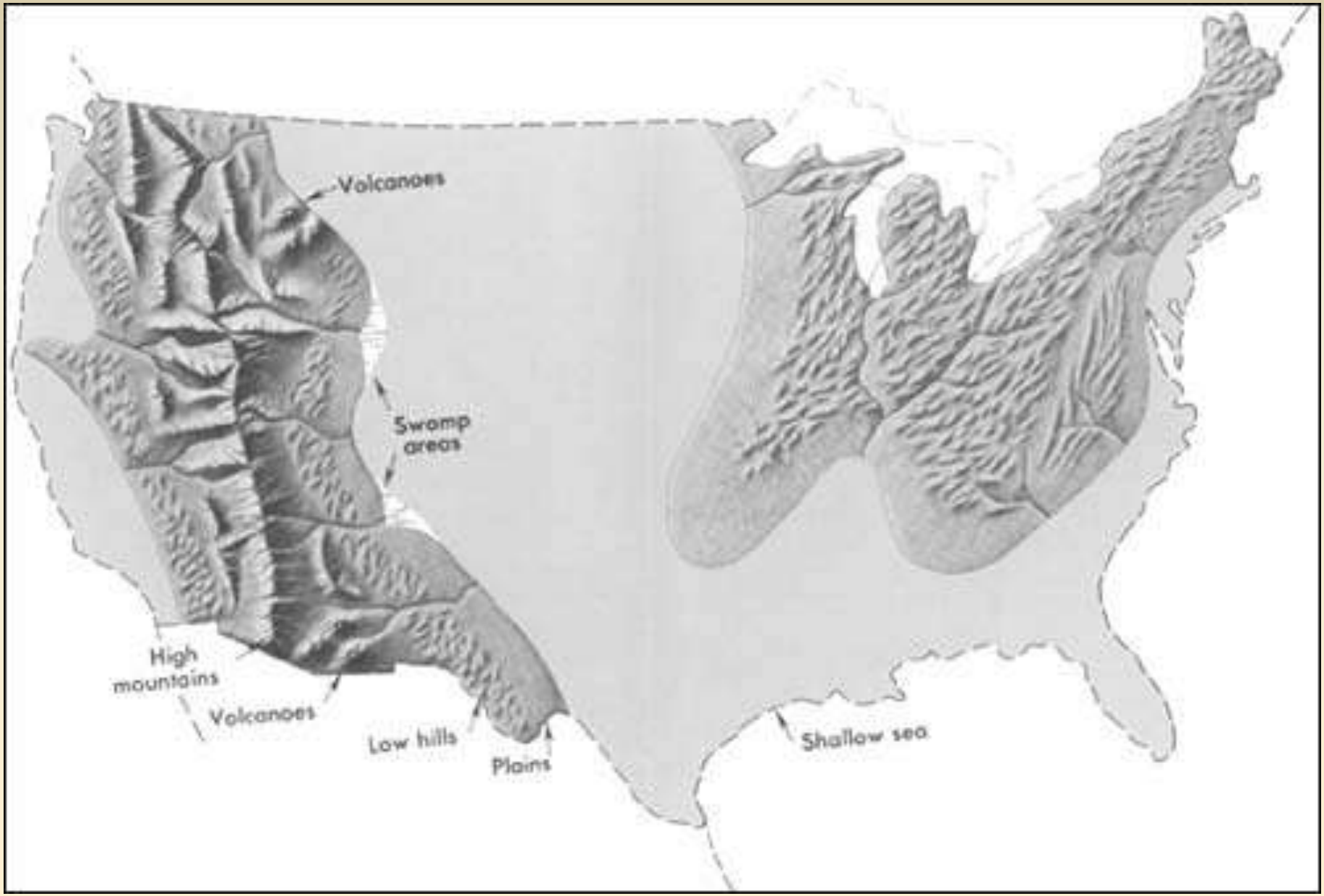
Cretaceous

- Was a warm period with no ice caps at the poles.
- Much of what we now know as dry land - such as the Midwest of the USA - was underwater, since sea levels reached their highest ever during this time
- Ended with the most famous mass extinction in history - the one that killed the dinosaurs.

Cretaceous Continents



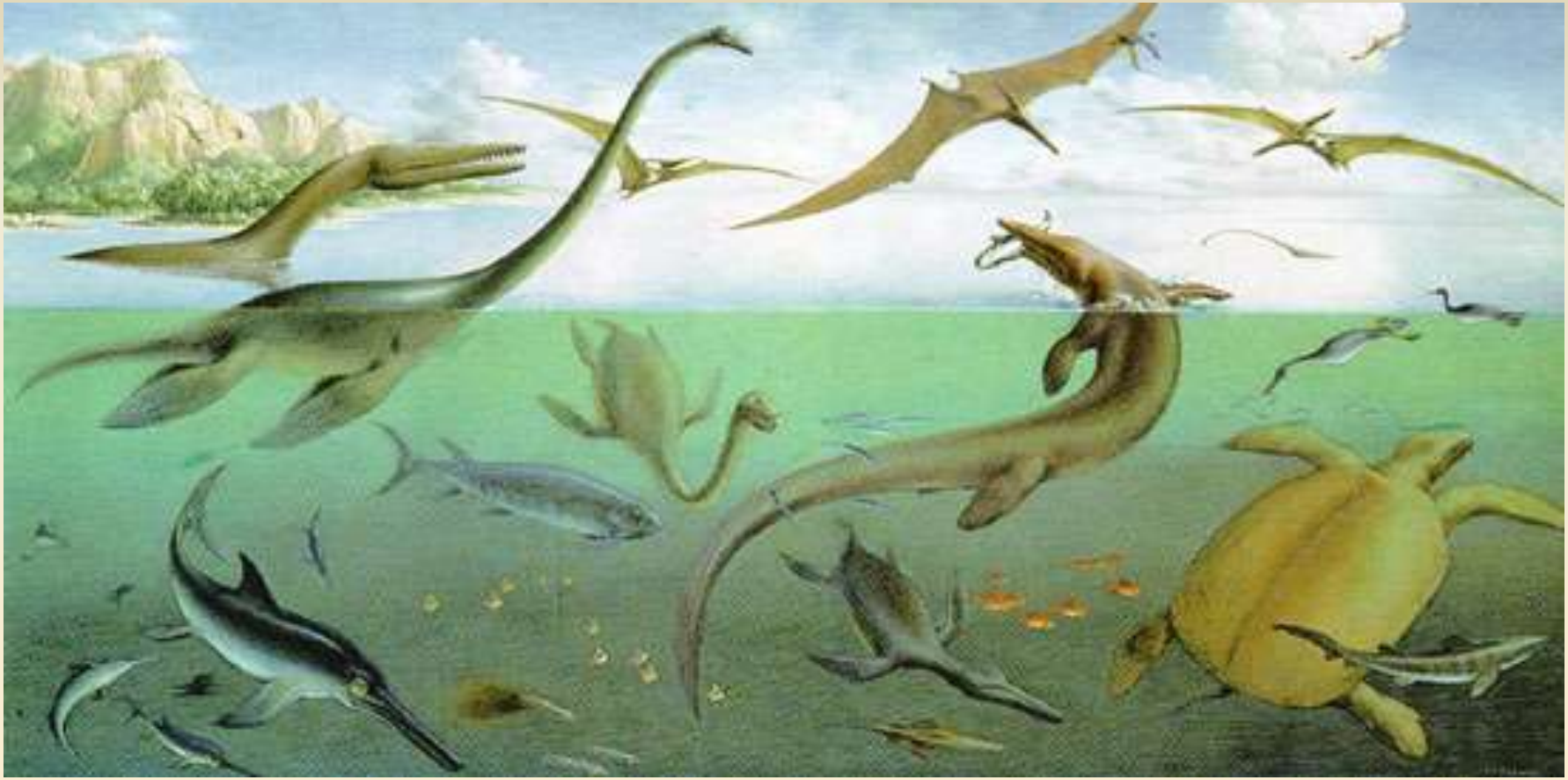
Cretaceous – Inland Seas



Ammonoids

The ammonoids, for example *Scaphites nodosus* were diverse and abundant during the Cretaceous, to be completely lost at the end of this Period.

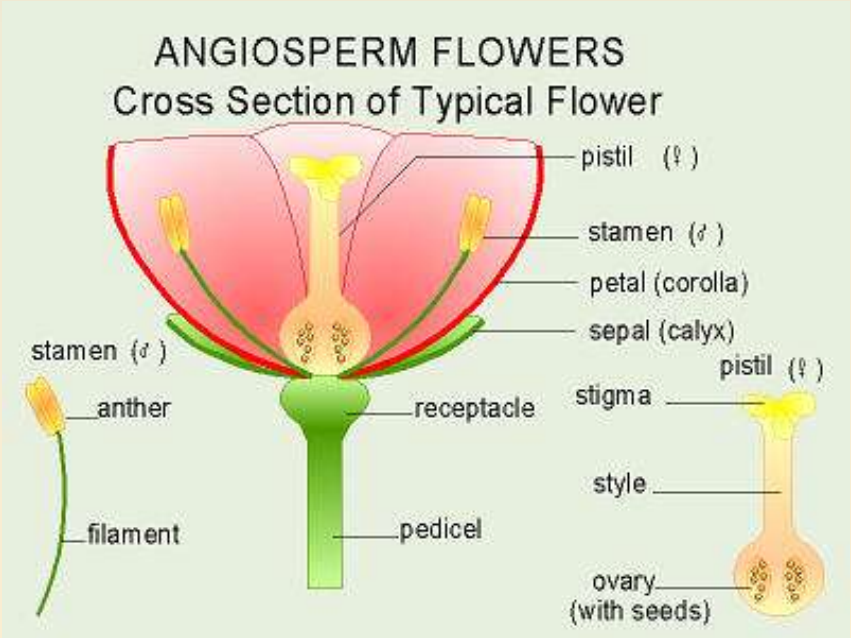
Cretaceous Marine Reptiles



Cretaceous landscape

Cretaceous landscape

Angiosperms appear in the Cretaceous



- Angiosperm plants are those that have flowers
- Major change in plant life – insects are now the pollinators
- Sets the stage for grasses to appear in Cenozoic

Archaefructus sinensis

125 million years old

Collected in Liaoning Province, China

Although it had no petals, this ancient flower had closed fruits that protected the seeds inside. This evolutionary leap separated flowering plants from other plants and probably led to their great success.

Primitive existing flowers

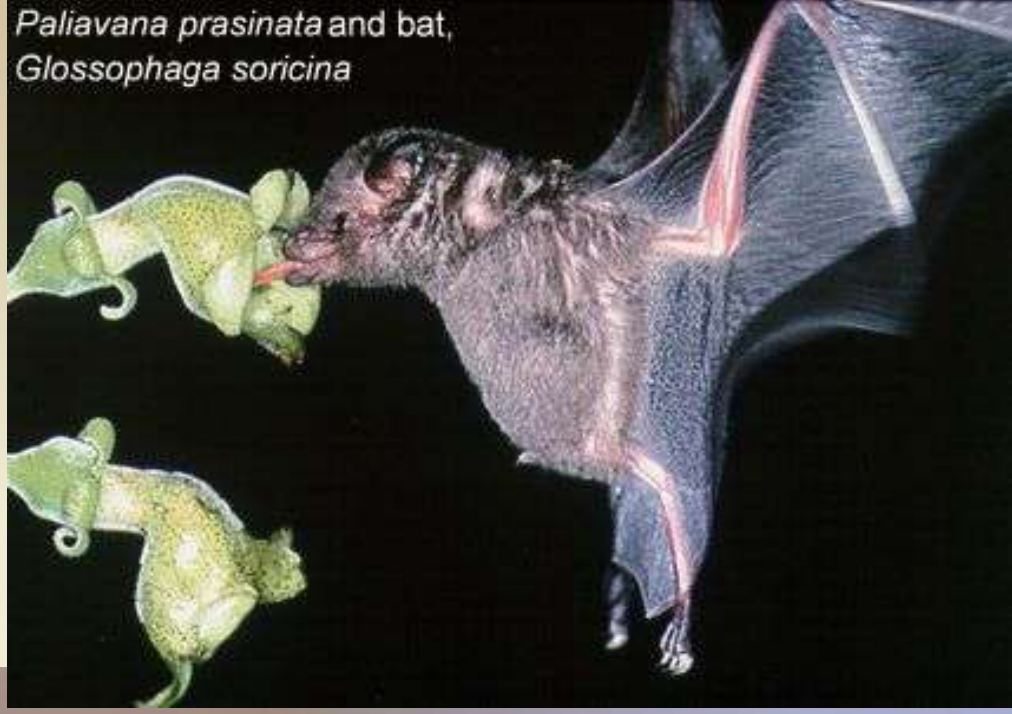
Amborella

Nymphaea

Angiosperms are special because:

- Insect-pollinated instead of wind pollinated
  - Insect relationship allows for new means of plant diversification: evolve to match a specific bug
- Animal-dispersed via fruits
  - Encase seeds bribing animals to disperse
- Animal and insect relationships allow more rapid dispersion + more remote existence
- Seed comes with its own early nutrition inside

Araucarian cone (sectioned), Jurassic, Patagonia


Paliavana prasinata and bat,
Glossophaga soricina

Duck-billed dinosaurs

Common herbivores from the upper Cretaceous period. The secret of their success perhaps lay with the duck-shaped bill that clipped vegetation and the many small teeth that ground it down.

Hypsibema missouriense

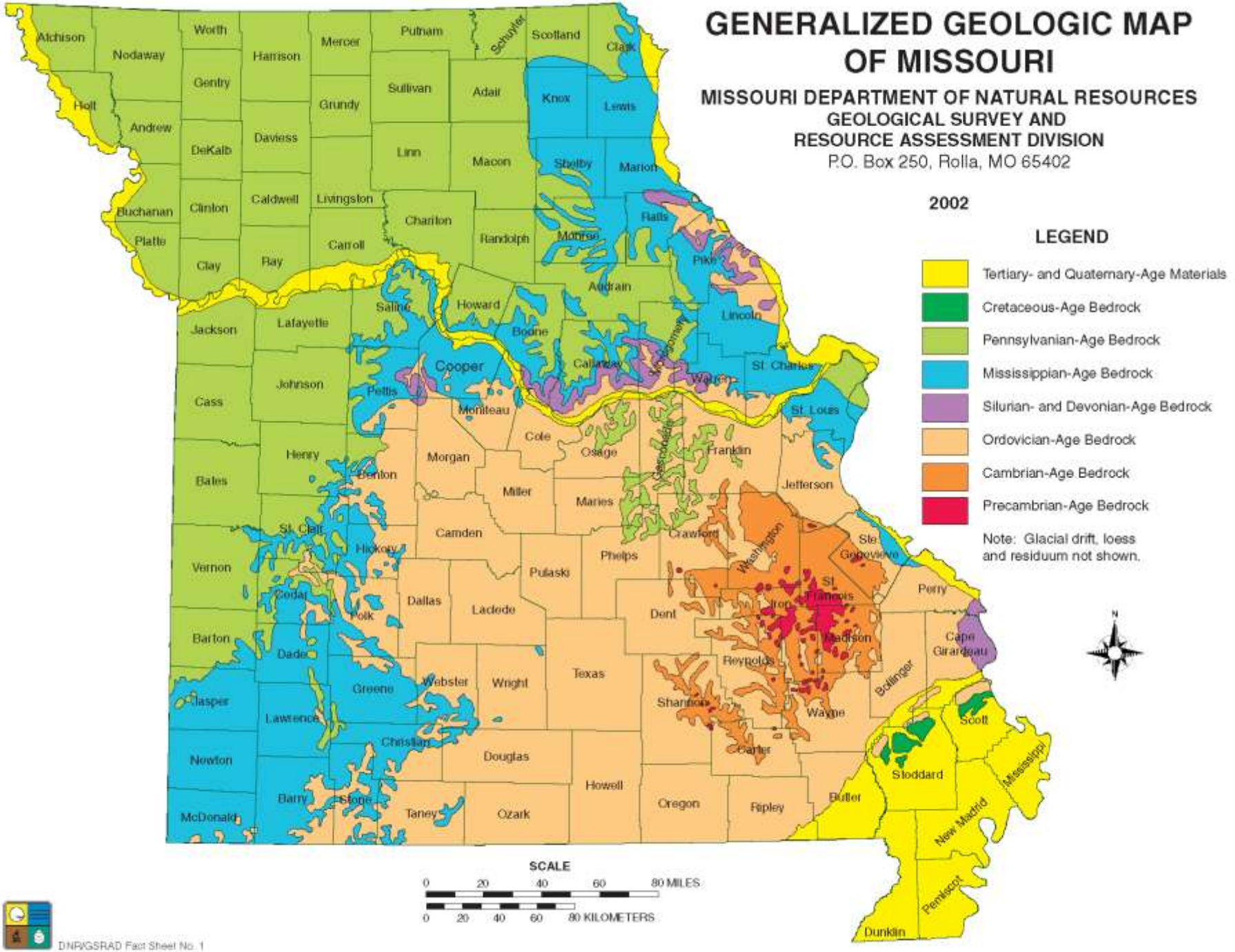
Hadrosaur discovered in 1942 by Dan Stewart, near the town of Glen Allen, MO, and became the state's official dinosaur

The hadrosaurs are known as the duck-billed dinosaurs due to the similarity of their head to that of modern ducks.

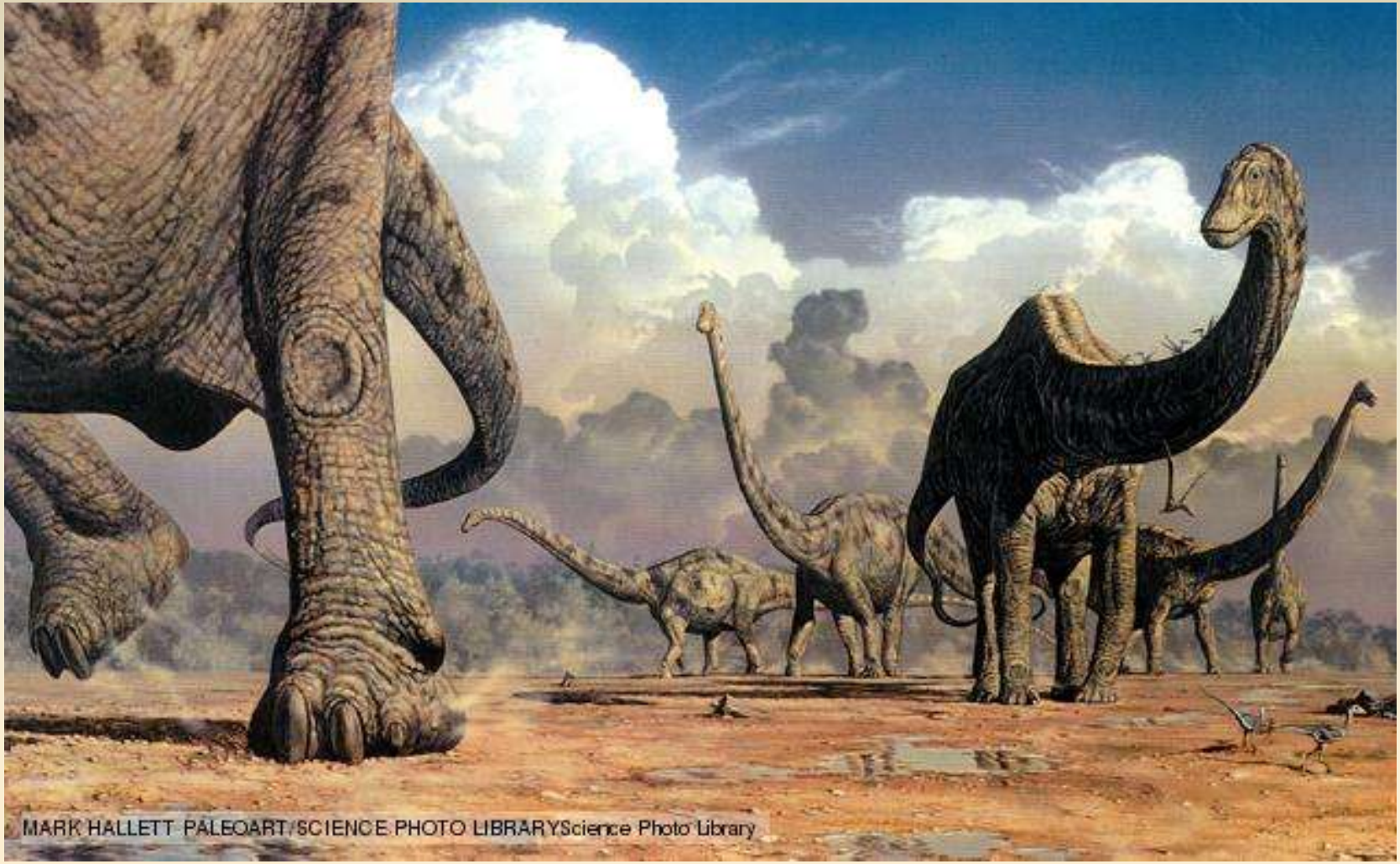
GENERALIZED GEOLOGIC MAP OF MISSOURI

MISSOURI DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY AND
RESOURCE ASSESSMENT DIVISION
P.O. Box 250, Rolla, MO 65402

2002



Sauropod Dinosaurs



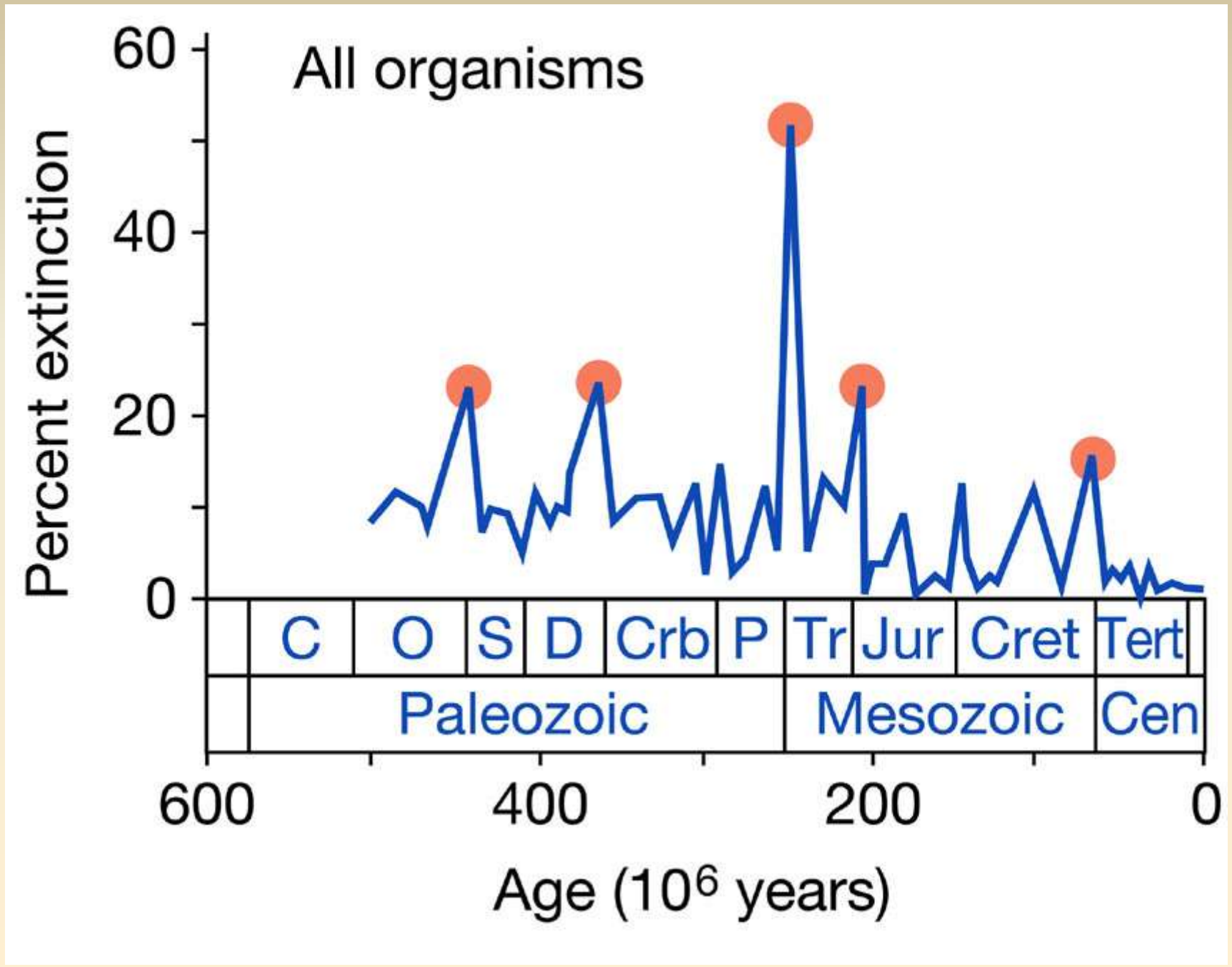
Tyrannosaurs

Includes the famous Tyrannosaurus rex as well as other large carnivores such as Albertosaurus and Tarbosaurus. They evolved in the late Cretaceous and their large size made them the top predators of the time

Tyrannosaurus

- The skull of Tyrannosaurus,
  - another theropod,
  - measured more than 1 m long

K/T Boundary Cretaceous Extinction


All organisms
Percent extinction
60
40
20
0
C
O
S
D
Crb
P
Tr
Jur
Cret
Tert
Paleozoic
Mesozoic
Cen
600
400
200
0
Age (10⁶ years)

K/T Boundary Extinction

- 65 MY ago
- Dinosaurs, pterosaurs, many marsupial mammals became extinct
- Extinction for terrestrial organisms 15%
- Marine extinctions at the generic level 70%
- All ammonites, rudists (bivalves), marine reptiles

Animals both on land and in the sea were affected. The extinction at the end of the Cretaceous **totally wiped out** these groups:

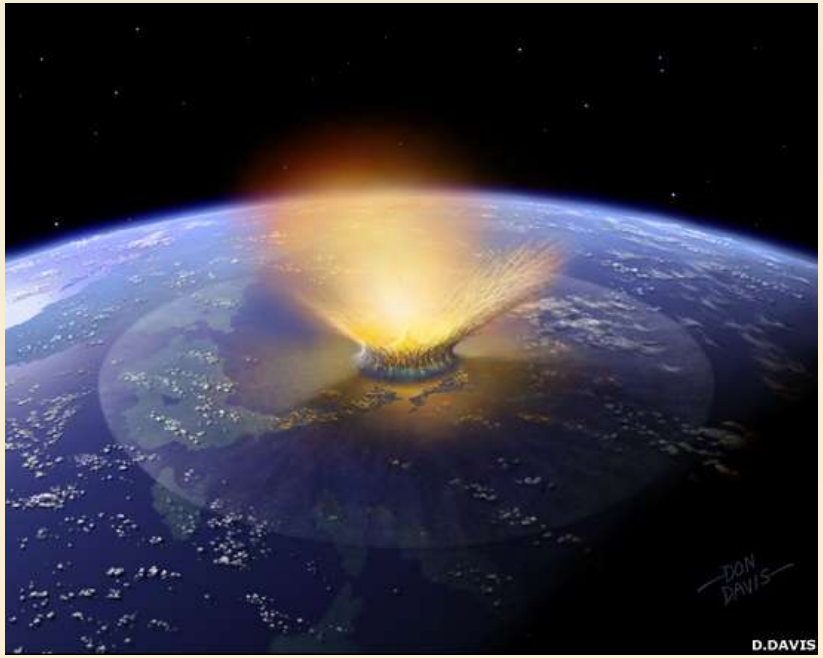
- **Dinosaurs**
- **Pterosaurs** (flying reptiles)
- **Ammonoids** (cephalopod molluscs)
- **Large marine reptiles** (**ichthyosaurs**, **plesiosaurs** & **mosasaurs**)
- **Rudists** (bivalve molluscs)
- and many other invertebrate taxa

- Many groups died out gradually, and others disappeared suddenly.
- The extinctions did not all happen simultaneously.
- On land, only small (less than 50 lb) animals survived.
- Of the reptiles, only turtles, snakes, lizards, crocodiles, and the tuatara (a reptile from New Zealand) survived the extinction.
- More than 75% of the marine plankton species disappeared at the end of the Cretaceous.

Causes of Extinction at the K/T Boundary?

- Sea Level changes
- Temperature changes
- Increased seasonality
- Changes in plant distribution and extinction
- Increased competition with mammals
- Bolide collision

Cretaceous Asteroid Impact

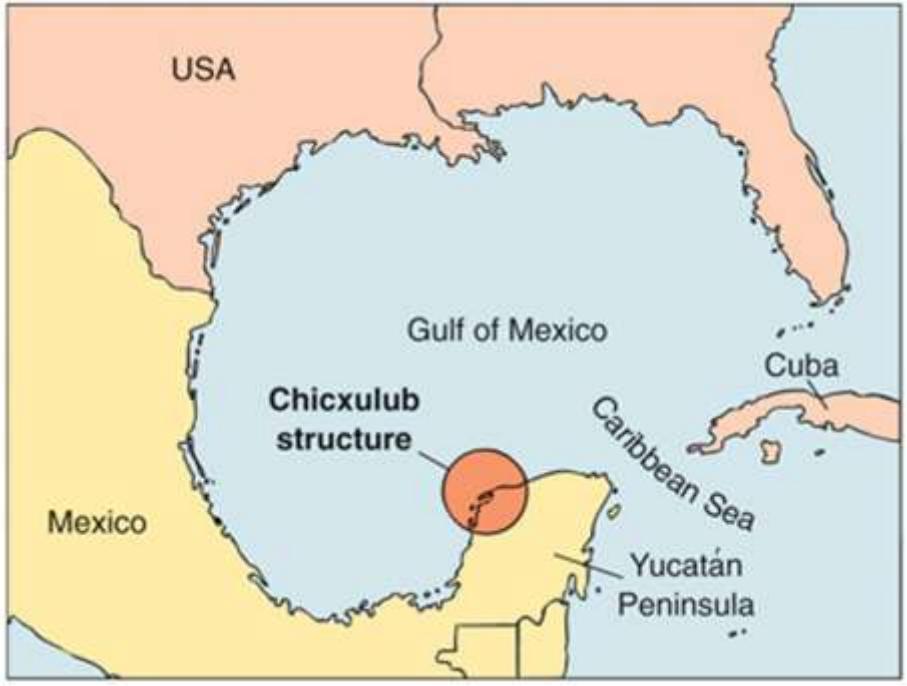


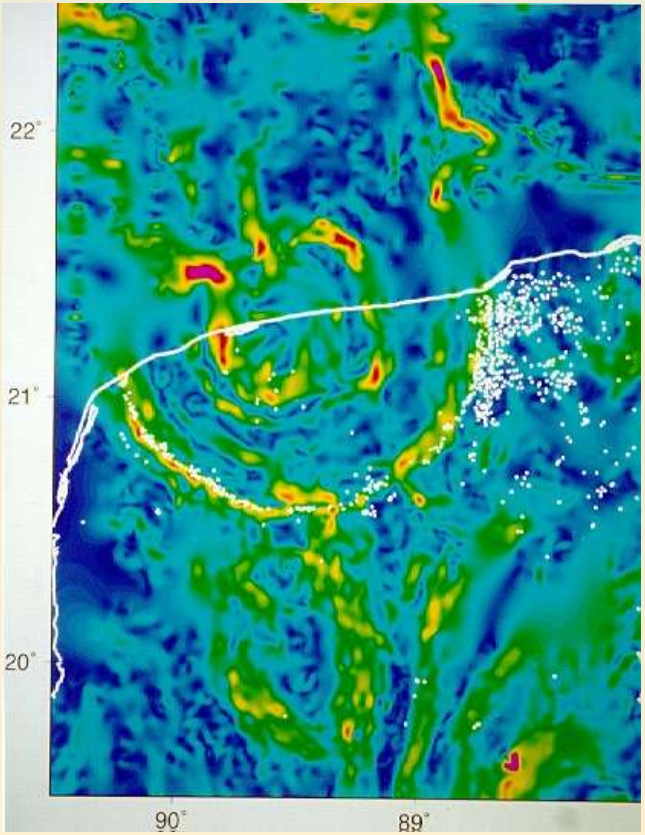
Cretaceous-Tertiary Mass Extinction

Famed for the death of the dinosaurs. However, many other organisms perished at the end of the Cretaceous including the ammonites, many flowering plants and the last of the pterosaurs. Some groups had been in decline for several million years before the final event that destroyed them all.

Where is the impact crater?

The most likely location of an impact structure of the proper age is the **Chicxulub structure**, a buried circular crater-like structure on the Yucatan Peninsula of Mexico.





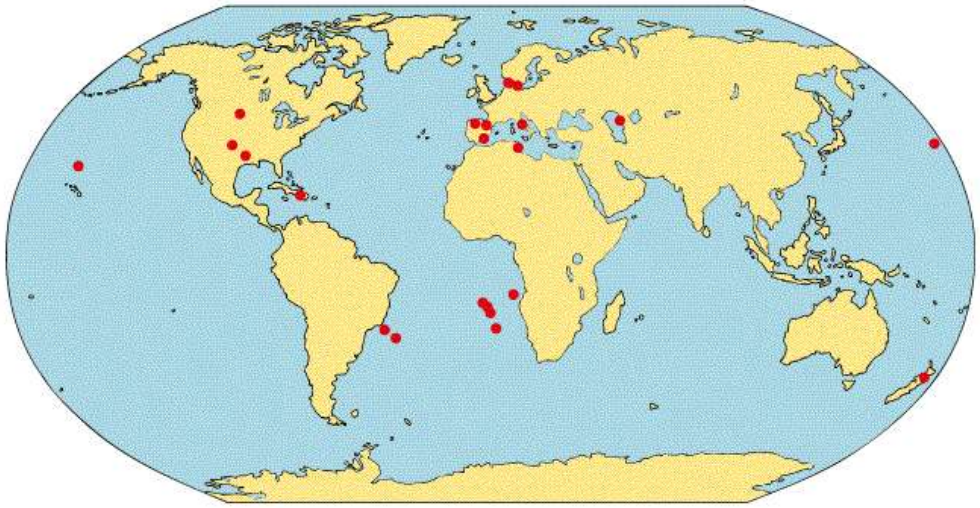
Luis and Walter Alvarez

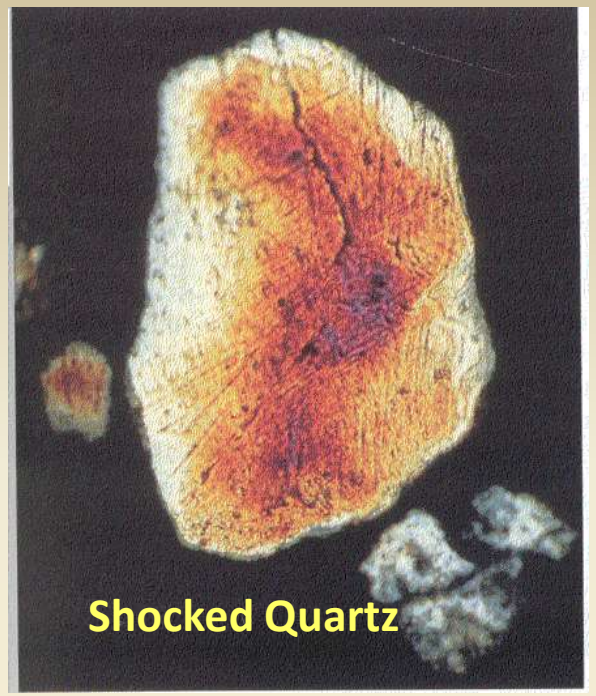
Luis and Walter Alvarez stand by the rock layers near Gubbio, Italy, where unusually high traces of iridium were found at the Cretaceous-Tertiary boundary.

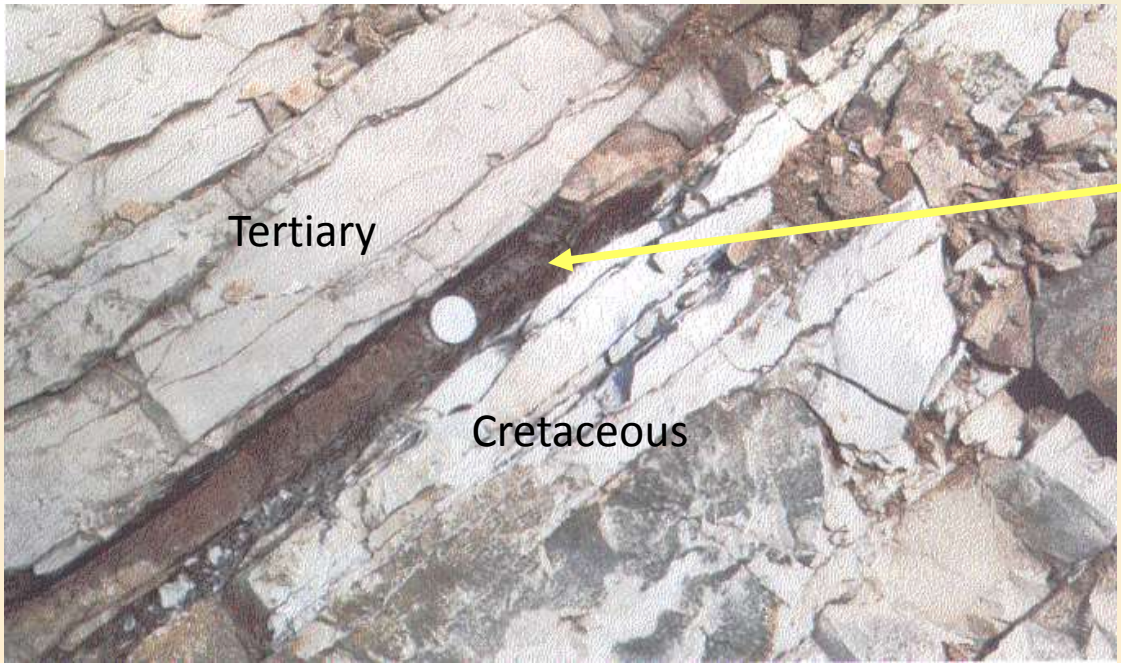
Evidence for extraterrestrial causes?

- A thin layer of clay with a concentration of **iridium** is found at the boundary at the end of the Cretaceous Period (the boundary clay).
- Since iridium is more abundant in meteorites than in normal Earth's surface rocks, it was proposed that a large impact of an extra terrestrial object with the Earth at the end of the Cretaceous might have spread iridium around the globe.
- Other things may also have been responsible for the presence of the iridium, and all possibilities must be considered.

Occurences of Iridium-rich sediments at the K/T







Iridium-rich clay layer Gubbio, Italy

Impact Consequences

- According to the impact hypothesis
  - 60 times the mass of the meteorite was blasted from the crust high into the atmosphere
  - heat generated at impact started raging forest fires that added more particulate matter to the atmosphere
- Sunlight was blocked for several months
  - caused a temporary cessation of photosynthesis
  - food chains collapsed and extinctions followed

Acid Rain

- With sunlight greatly diminished, Earth's surface temperatures were drastically reduced, adding to the biologic stress

- Another proposed consequence of an impact is that sulfuric acid (H_2SO_4) and nitric acid (HNO_3) resulted from vaporized rock and atmospheric gases

- Both would have contributed to strongly acid rain that might have had devastating effects on vegetation and marine organisms

Killing mechanisms:

1. Atmospheric debris

2. Acid rain

3. Widespread wildfires

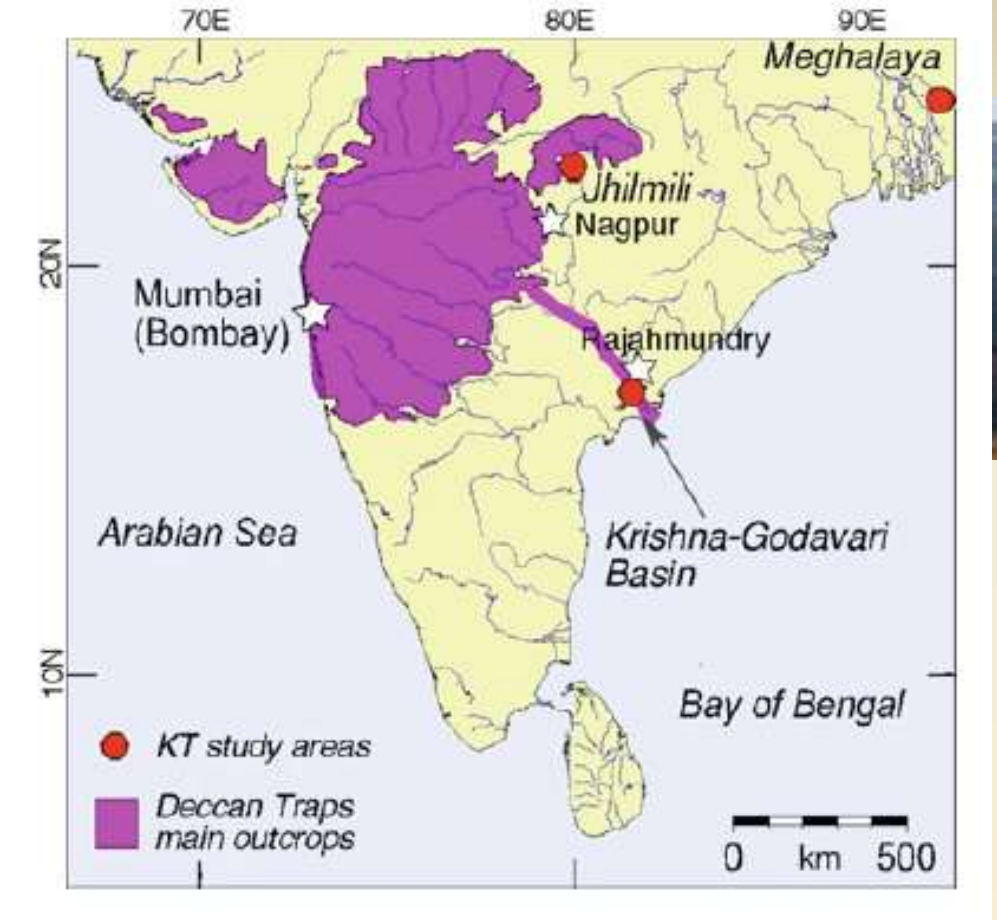
4. Earthquakes of magnitude 13 on Richter scale

5. Tsunami 4 km high

Possible Terrestrial Causes

- Volcanic eruptions causing ash and aerosols in atmosphere leading to a drop in temperature. Volcanism was widespread toward the end of the Cretaceous, and volcanic ash can be a source of iridium.
- Other elements in the boundary clay like antimony and arsenic are common in volcanic ash but not in meteorites.

Deccan Traps – volcanic outpourings



The Deccan eruptions released copious quantities of SO_2 into the atmosphere in multiple events over several thousand years. Quantities released are estimated to have been around 150 gigatons SO_2 per event for about 30 eruptive events overall. This would have resulted in significant cooling, acid rain, and perhaps ocean acidification globally.

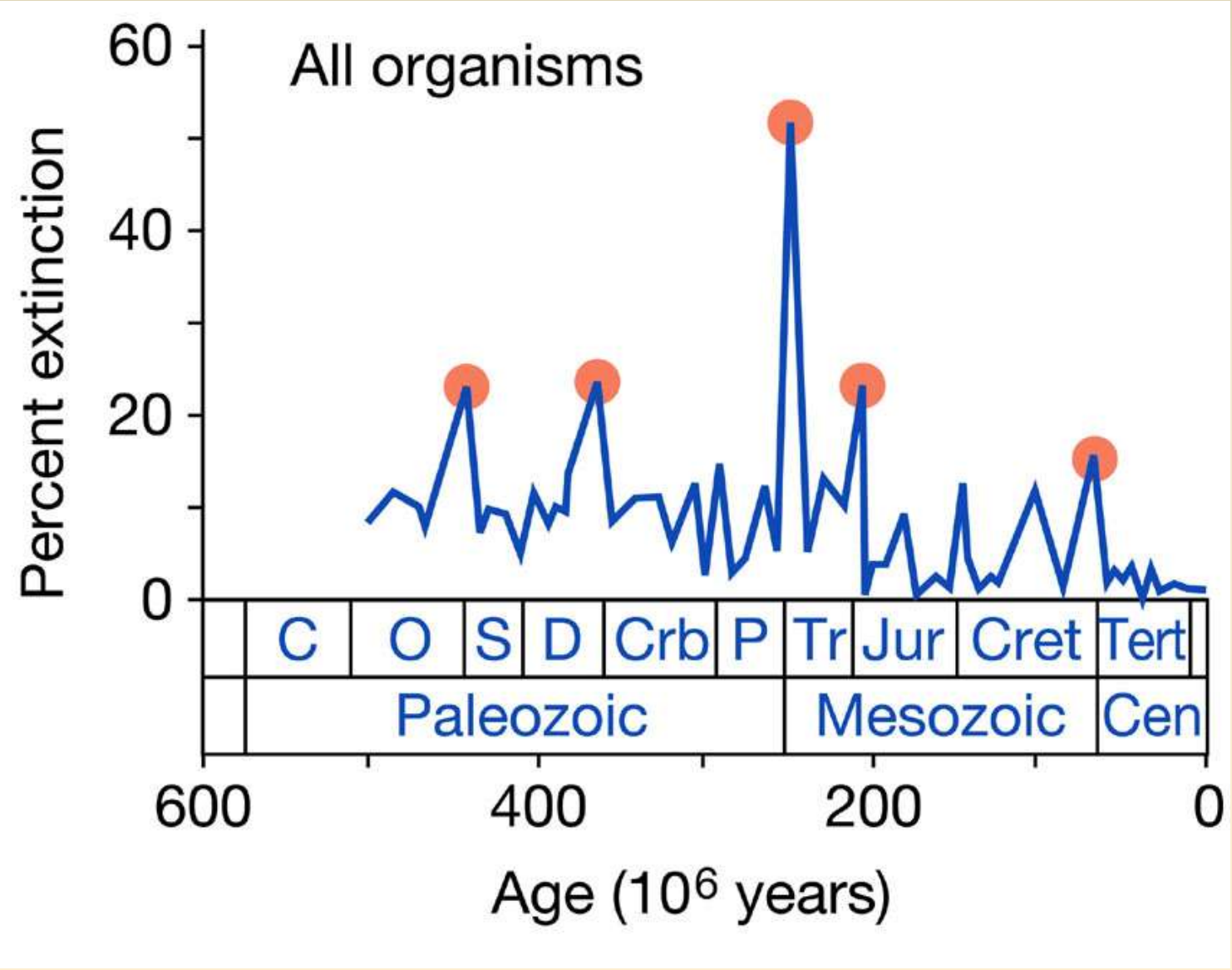
Volcanic Model

- Iridium as aerosol from volcanism
- Large eruption of flood basalts
  - Deccan Plateau (size of France)
  - Periodicity of 30 MY of basalts coincide with extinction peaks
- Sulfates >> acid rain > pH
- Cooling due to erupted ash
- Eruptions ejected vast amounts of carbon dioxide, caused ocean acidification, poisoning the phytoplankton (single-celled algae) that larger marine animals relied on for food.
- levels of CO2 greenhouse gas were able to rise unchecked, temperatures may have increased by as much as 10°C

Mass extinctions

- A **mass extinction** occurs when a large fraction of all living species becomes rapidly extinct.
- Identified when extinction rates rise well above normal “background extinction”.
- The fossil record shows that at least five major mass extinctions have occurred in the past 500 million years.
- Impacts of asteroids on Earth are suspected as a primary cause of mass extinction.

5 Great Mass Extinctions!



The “Big Five”

Mass Extinction	Date (MYA)	% families lost	% species lost
end-Ordovician	439	26	85
late-Devonian	367	22	83
end-Permian	250	52	96
end-Triassic	215	22	80
Cretaceous-Tertiary (K-T)	65	16	76

Flood basalt eruptions

Large-scale volcanic activity, both in terms of extent and duration, that can occur on land or on the ocean floor. A flood basalt may continue to erupt for tens of thousands - possibly millions - of years and the lava can cover hundreds of thousands of kilometres. The huge volume of lava is accompanied by a similarly large release of volcanic gases such as sulphur dioxide and carbon dioxide. These can affect climate and cause acid rain, so flood basalts are thought to be a potential cause of mass extinctions.

Impact events

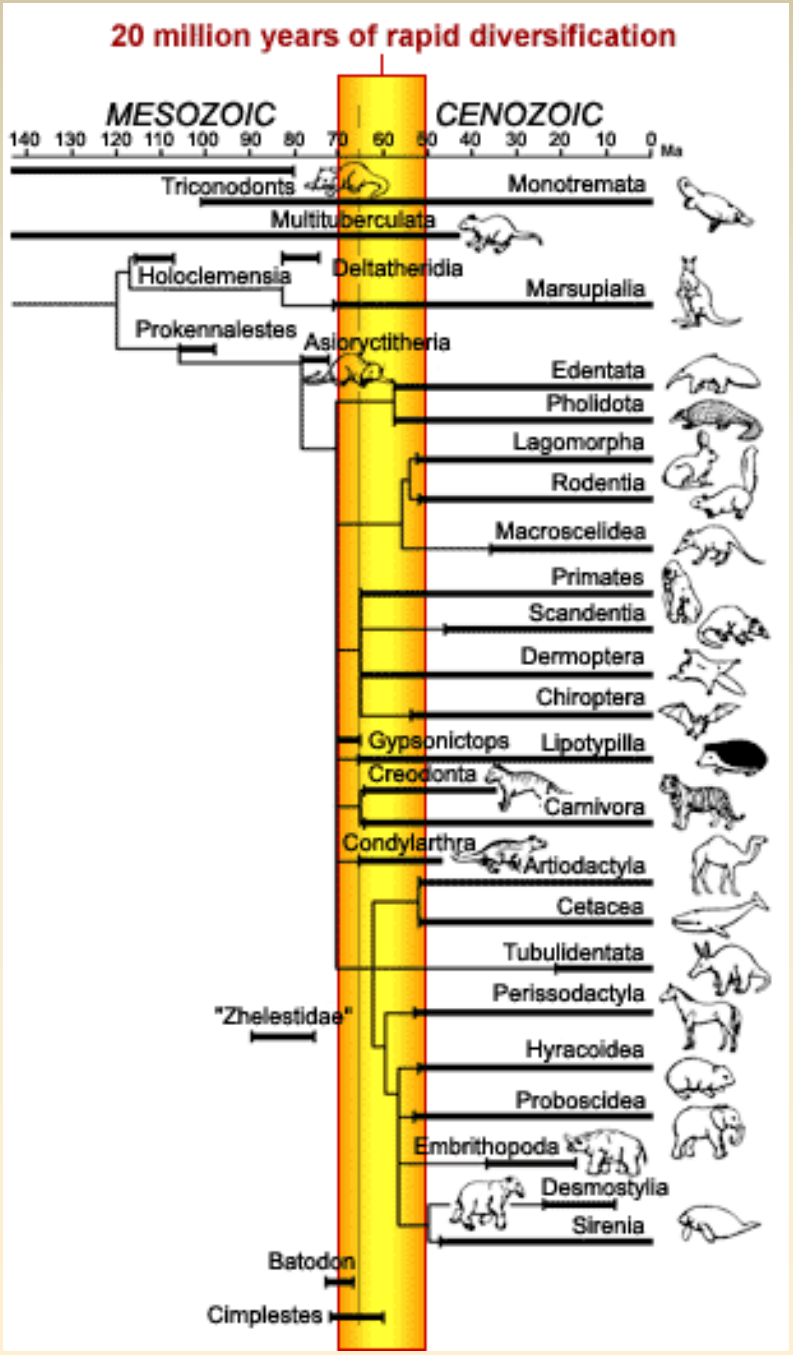
Impact events, proposed as causes of mass extinction, are when the planet is struck by a comet or meteor large enough to create a huge shockwave felt around the globe. Widespread dust and debris rain down, disrupting the climate and causing extinction on a global, rather than local, scale

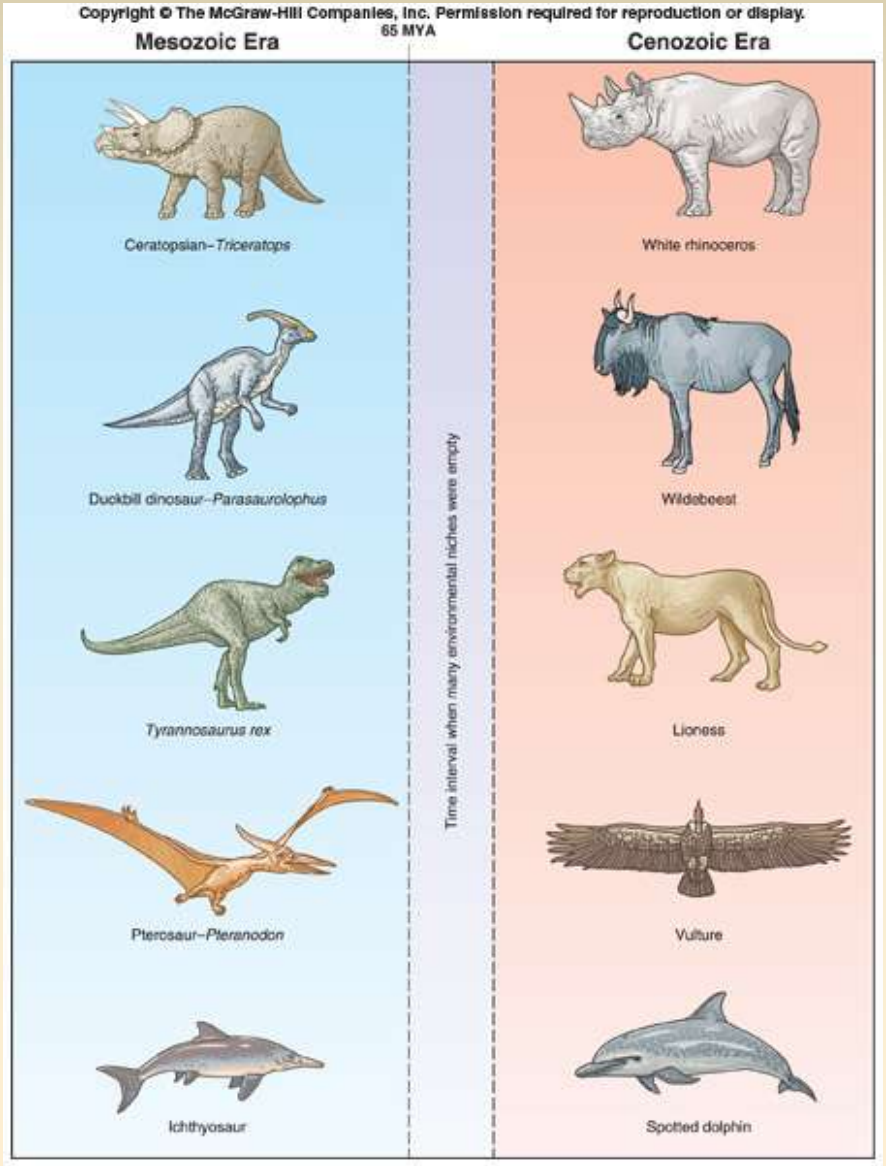
Climate change

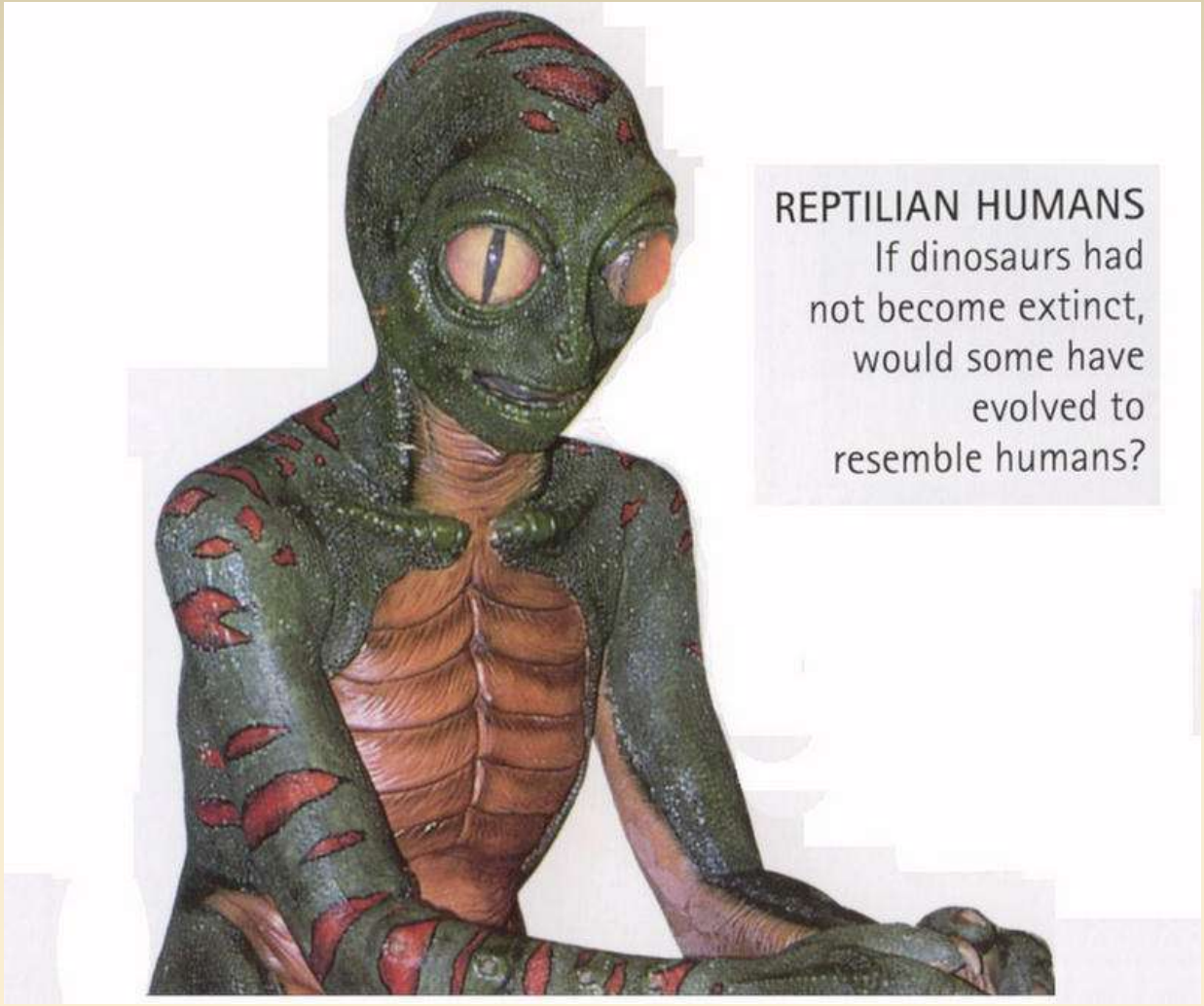
Over geological time, the Earth's dominant climate has gone from ice age to tropical heat and from steamy jungles to searing deserts. When such climate change occurs abruptly - either in the form of a global warming or cooling - animals and plants have no time to adapt so mass extinctions can occur.


The Picture Library / Natural History MuseumThe Picture Library / Natural Hi

Mammals took over the role of the Dinosaurs.







REPTILIAN HUMANS

If dinosaurs had not become extinct, would some have evolved to resemble humans?

End