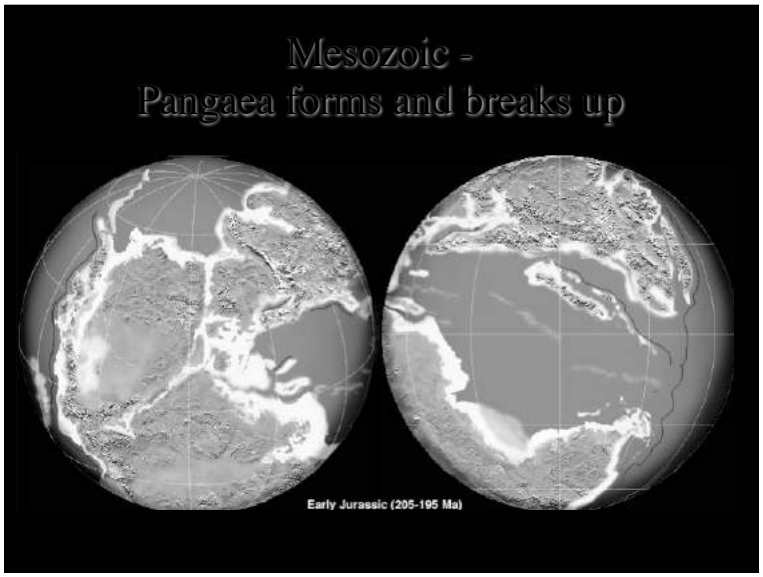
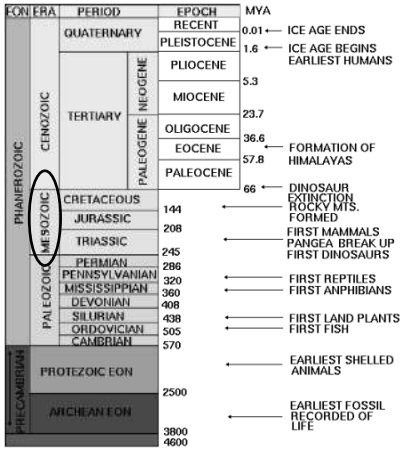


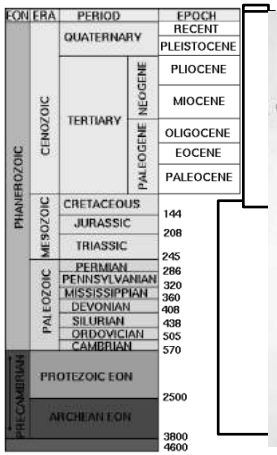
Extinct Land Plants - the Fossil Record

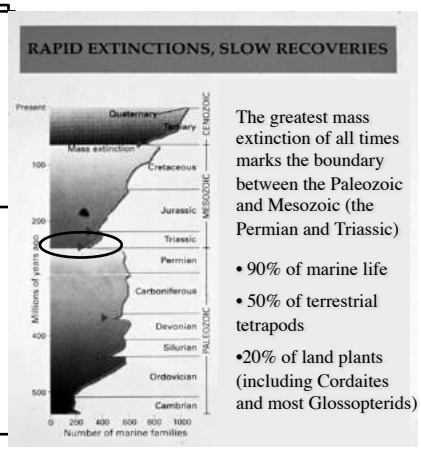


The basic nature of modern terrestrial ecosystems was established no later than by the end of the Paleozoic Era

- **Mesozoic Era** and the first part of the Cenozoic saw the most dramatic changes in world vegetation, flora, and fauna
- and the two greatest extinction events in the history of terrestrial ecosystems (Permian-Triassic boundary, K-T boundary)

Extinct Land Plants - the Fossil Record





The greatest mass extinction of all times marks the boundary between the Paleozoic and Mesozoic (the Permian and Triassic)

- 90% of marine life
- 50% of terrestrial tetrapods
- 20% of land plants (including Cordaites and most Glossopterids)

Extinct Land Plants - the Fossil Record

Triassic Period (245 - 208 mya)

Dinosaurs arose in the late Triassic from thecodont reptiles.

The first true dinosaurs were the ceratosaurians, or horned dinosaurs.

Plateosaurus (larger) spies two *Yaleosaurus* (left) and a smaller *Coelophysus* behind. Note the dominant vegetation type of Cycads (*Bjuvia)*.

Extinct Land Plants - the Fossil Record

Triassic Period (245 - 208 mya)

Plateosaurus (larger) spies two *Yaleosaurus* (left) and a smaller *Coelophysus* behind. Note the dominant vegetation type of Cycads (*Bjuvia)*.

The Triassic (and Jurassic) is known as the "Age of Cycads" as this gymnosperm group rapidly diversified after initially appearing earlier in the Permian.

Modern cycad - *Dioon*

Extinct Land Plants - the Fossil Record

Triassic Period (245 - 208 mya)

Other elements of this cosmopolitan Triassic flora:

Seed ferns

The glossopterids persisted in Gondwana but were gradually replaced by a new flora characterized by the seed fern, *Dicroidium*. By the close of the Triassic the glossopterids were extinct.

Dicroidium sp. from New South Wales, Australia

Extinct Land Plants - the Fossil Record

Triassic Period (245 - 208 mya)

Other elements of this cosmopolitan Triassic flora:

Primitive conifers and ginkgoes

The big trees of the Triassic were primitive lineages of conifers and ginkgoes

Extinct Land Plants - the Fossil Record

Triassic Period (245 - 208 mya)

Other elements of this cosmopolitan Triassic flora:

Primitive conifers and ginkgoes

The Petrified Forest National Park during the late Triassic, (225 mya)

The gymnosperms replaced lycopsids and sphenopsids which were reduced in size and diversity

Araucarioxylon, largest and most abundant of the park's fossil conifer trees, towers over the horsetail *Neocalamites*

Extinct Land Plants - the Fossil Record

Triassic Period (245 - 208 mya)

Other elements of this cosmopolitan Triassic flora:

Primitive conifers and ginkgoes

Araucaria auracana - Chile

The Petrified Forest National Park today

Araucarioxylon represents one of a number of extinct genera of the extant araucariads placed in Araucariaceae (now strictly Southern Hemisphere) that comprise the petrified rocks in Arizona - more cosmopolitan in Mesozoic

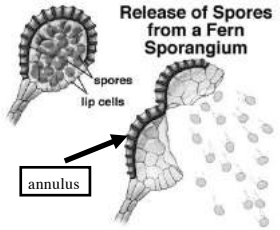
Extinct Land Plants - the Fossil Record

Triassic Period (245 - 208 mya)

Other elements of this cosmopolitan Triassic flora:

"Modern" families of ferns

New lineages of primitive and advanced ferns (with an annulus) are seen in the understory



Extinct Land Plants - the Fossil Record

Triassic Period (245 - 208 mya)

Other elements of this cosmopolitan Triassic flora:

"Modern" families of ferns

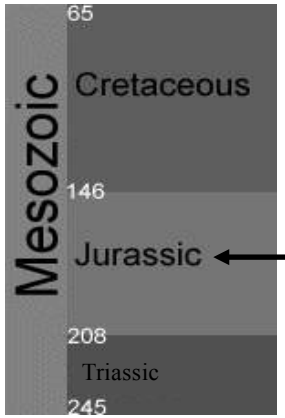
These include:

Schizaceaceae - climbing fern

Cyathaceae - tree fern

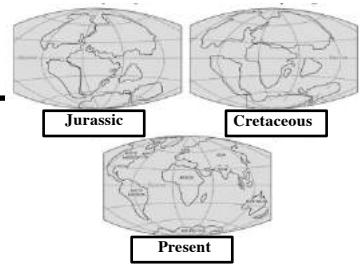
Osmundaceae - cinnamon fern

Extinct Land Plants - the Fossil Record



Jurassic Period (208 - 146mya)

The Jurassic saw the major initiation of the breakup of Pangaea, very warm temperatures worldwide, and the rise of sea levels

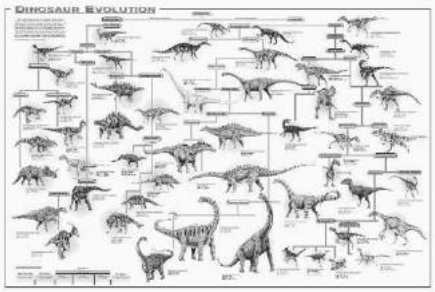


Extinct Land Plants - the Fossil Record

Jurassic Period (208 - 146mya)

The major events of the Jurassic were the explosive adaptive radiation of dinosaurs . . .

"Age of Dinosaurs" (and Cycads)



Extinct Land Plants - the Fossil Record

Jurassic Period (208 - 146mya)

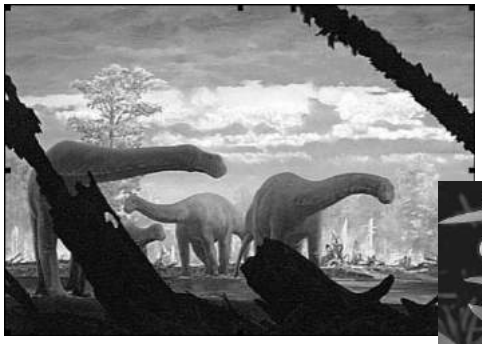
The major events of the Jurassic were the explosive adaptive radiation of dinosaurs and rise of the birds (avian dinosaurs)

Archaeopteryx fossil from Germany (150 Mya)

Extinct Land Plants - the Fossil Record

Jurassic Period (208 - 146mya)

Despite the breakup of Pangaea, there were no impassable barriers to dispersal and the warm world-wide climate allowed for an even more cosmopolitan flora than seen in the Triassic



mid-Jurassic Argentina

Sauropods walk under Araucariaceae and Podocarpaceae (below) (gymnosperms)

Extinct Land Plants - the Fossil Record

Jurassic Period (208 - 146mya)

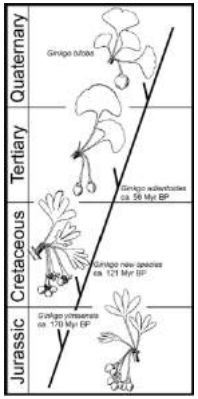
Despite the breakup of Pangaea, there were no impassable barriers to dispersal and the warm world-wide climate allowed for an even more cosmopolitan flora than seen in the Triassic

Dicroidium seed ferns, first seen in the Triassic, diversify tremendously especially in Gondwana

Extinct Land Plants - the Fossil Record

Jurassic Period (208 - 146mya)

"Modern" genera are first seen for *Ginkgo* . . .



Extinct Land Plants - the Fossil Record

Jurassic Period (208 - 146mya)

"Modern" genera are first seen for *Ginkgo* and *Equisetum* (horsetail)

Extinct Land Plants - the Fossil Record

Jurassic Period (208 - 146mya)

The Jurassic terrestrial environments saw an increase not only in gymnosperm groups such as the cycads and ginkgoes, but also the extinct lineage cycadeoids. The cycadeoids, sometimes known as the Bennettitales, produced leaves that superficially resembled cycad leaves.

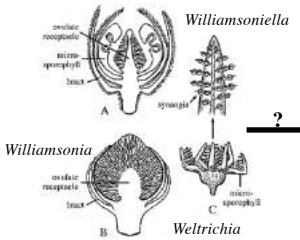
A. Williamsonia

B. Cycadeoidea

Extinct Land Plants - the Fossil Record

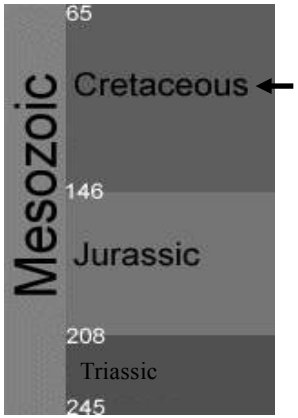
Jurassic Period (208 - 146mya)

The Jurassic terrestrial environments saw an increase not only in gymnosperm groups such as the cycads and ginkgoes, but also the extinct lineage cycadeoids. The cycadeoids, sometimes known as the Bennettitales, produced leaves that superficially resembled cycad leaves.



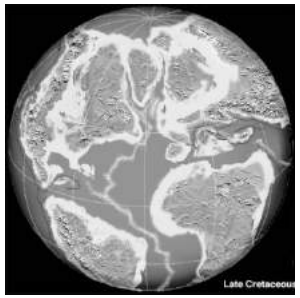
These reproductive structures are sometimes interpreted as "flowers" and the cycadeoids were suggested as ancestors or sisters to the flowering plants

Extinct Land Plants - the Fossil Record



Cretaceous Period (146 - 65 mya)

The Cretaceous was the period of major fragmentation of Pangaea begun in the Jurassic and of world-wide warm temperatures and high sea levels



Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

Near the Jurassic/ Cretaceous border, the first Angiosperms or flowering plants are seen

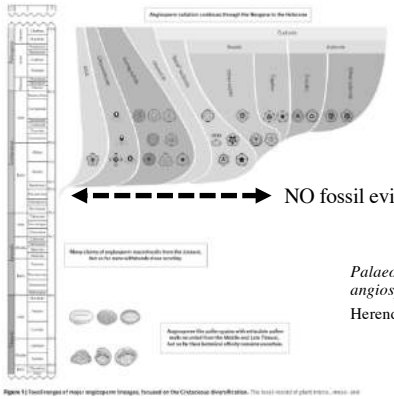
The earliest fossils to date come from 127 mya in China

Archeafructus reconstruction

Fossil *Archeafructus*

Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

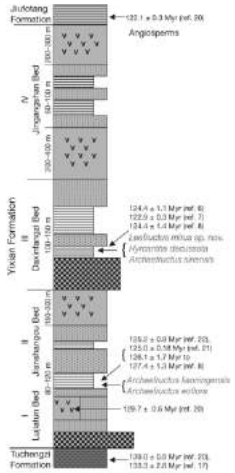


NO fossil evidence of flowering plants in Jurassic

Palaeobotanical redux: revisiting the age of the angiosperms

Herendeen et al. 2017. *Nature Plants*

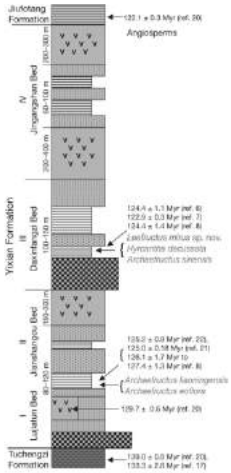
Extinct Land Plants - the Fossil Record



Cretaceous Period (146 - 65 mya)

Leefructus mirus – the earliest "eudicot" fossil: 124 mya (China). Eudicots are the success story of flowering plants.

Extinct Land Plants - the Fossil Record

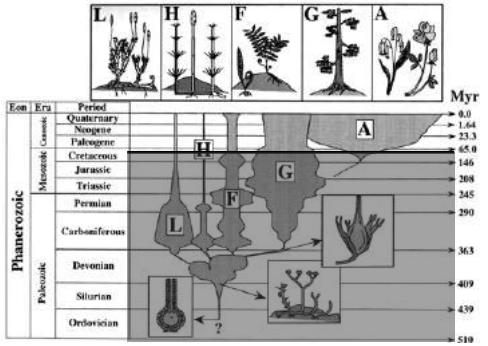


Cretaceous Period (146 - 65 mya)

Archaefructus and *Leefructus*
-the rise of Angiosperms

Extinct Land Plants - the Fossil Record

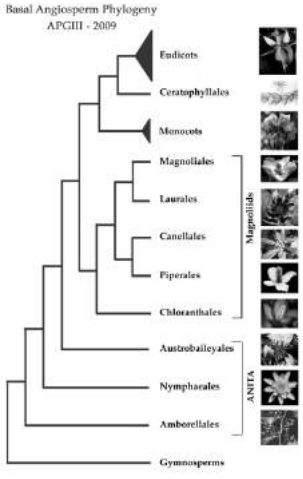
Cretaceous Period (146 - 65 mya)



All lineages of land plants have thus made their appearance by the Cretaceous

Many of the lineages, however, never make it into the Cenozoic Era and are only seen in the fossil record

Extinct Land Plants - the Fossil Record

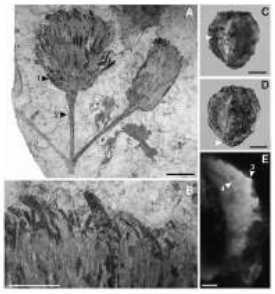


Cretaceous Period (146 - 65 mya)

By the close of the Cretaceous and the Mesozoic Era, flowering plants already had diverged into all the major lineages shown here.

Most of the major families of the tropical forest appeared in mid-Cretaceous

Extinct Land Plants - the Fossil Record



Eocene Patagonia Fossils of the Daisy Family

Science, 2010

Cretaceous Period (146 - 65 mya)

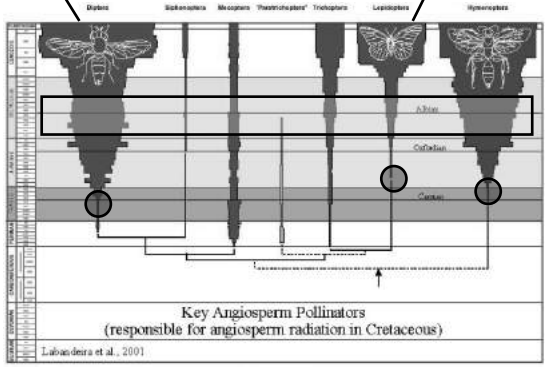
Majority of families, except for the most recent, are seen in the fossil record by the beginning of the Tertiary Period in the Cenozoic Era

Asteraceae is not seen until 48 mya in Tertiary rocks of South America

Flowering Plants and Their Pollinators

Does the timing of Angiosperm & pollinator radiations fit?

No & Yes — Angiosperms co-opted already diverging animal lineages in Early Cretaceous



Angiosperm evolution

Pollinator evolution

Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

Although not a strict co-evolution, as insects group had already diverged by the Cretaceous, the relationship between insects and flowering plants for pollination purposes and herbivore interactions spurred speciation in both groups

Hymenoptera

Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

Although not a strict co-evolution, as insects group had already diverged by the Cretaceous, the relationship between insects and flowering plants for pollination purposes and herbivore interactions spurred speciation in both groups

Lepidoptera

Extinct Land Plants - the Fossil Record

and birds

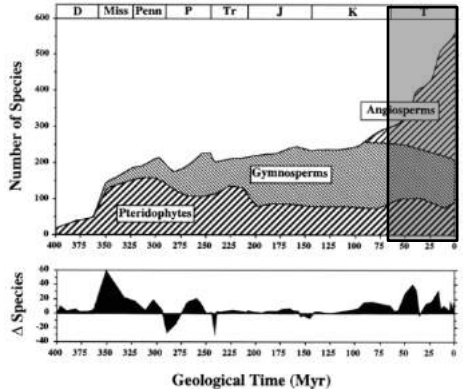
Cretaceous Period (146 - 65 mya)

Although not a strict co-evolution, as insects group had already diverged by the Cretaceous, the relationship between insects and flowering plants for pollination purposes and herbivore interactions spurred speciation in both groups

Diptera

Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

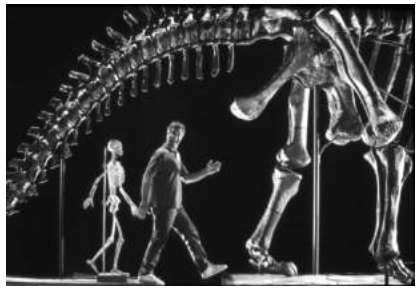


By the end of the Cretaceous, angiosperms dominate the paleofloras (fossil floras) at the expense of the gymnosperms, who in turn had previously out-competed the free sporing early vascular land plants

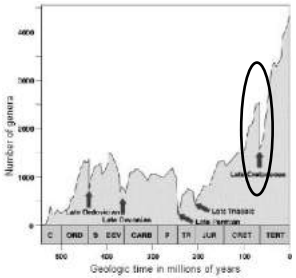
Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

The close of the Cretaceous and the beginning of the Tertiary (65 mya, KT or K-Pg boundary) was the second greatest extinction event in the history of earth that included the demise of all dinosaurs except for birds



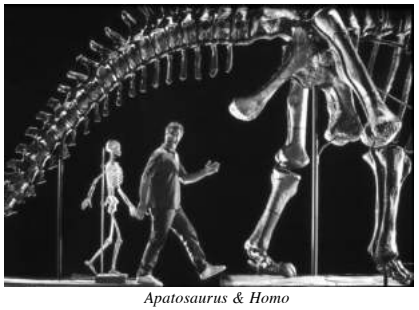
Apatosaurus & Homo



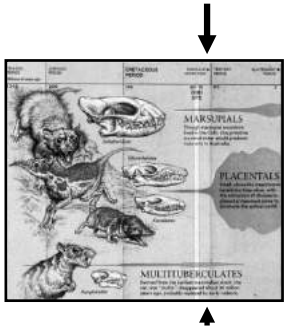
Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

The extinction of the diverse dinosaur lineage paved the way for the radiation of placental mammals and eventually humans - the mammal lineage dating back perhaps as far back as the Jurassic



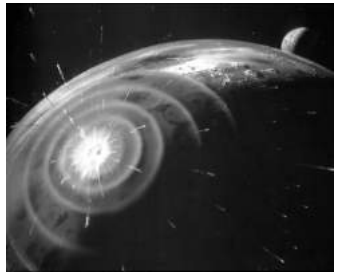
Apatosaurus & Homo

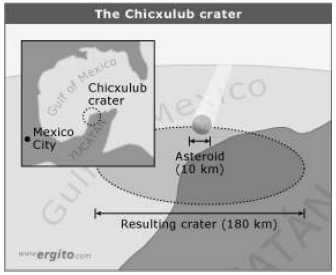


Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

A likely scenario for this extinction event - involving an asteroid collision off of the Yucatan Peninsula and resulting "dust winter" - affected both marine and terrestrial animals, but there is not as clear an effect on floras as was seen at the Permian-Triassic





Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

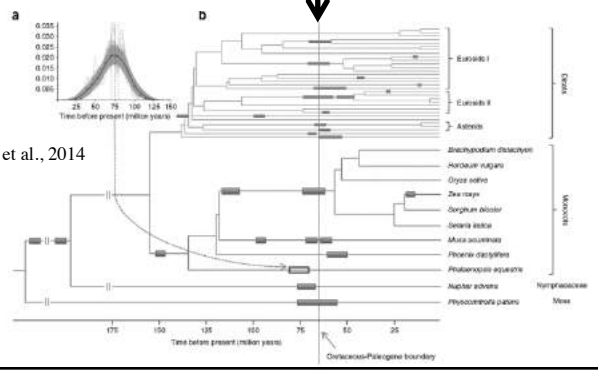
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

Tangled up in two: a burst of genome duplications at the end of the Cretaceous and the consequences for plant evolution

Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

Many independent WGD events in flowering plants appear correlated with the **KT (or K-Pg)** extinction event —



Vanneste et al., 2014

Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

Plant clades demonstrate incredible taxonomic resilience across faunal mass extinction boundaries perhaps owing to the great breadth of morphological, anatomical and physiological traits they contain — McElwain & Punyasena 2007 *TREE*