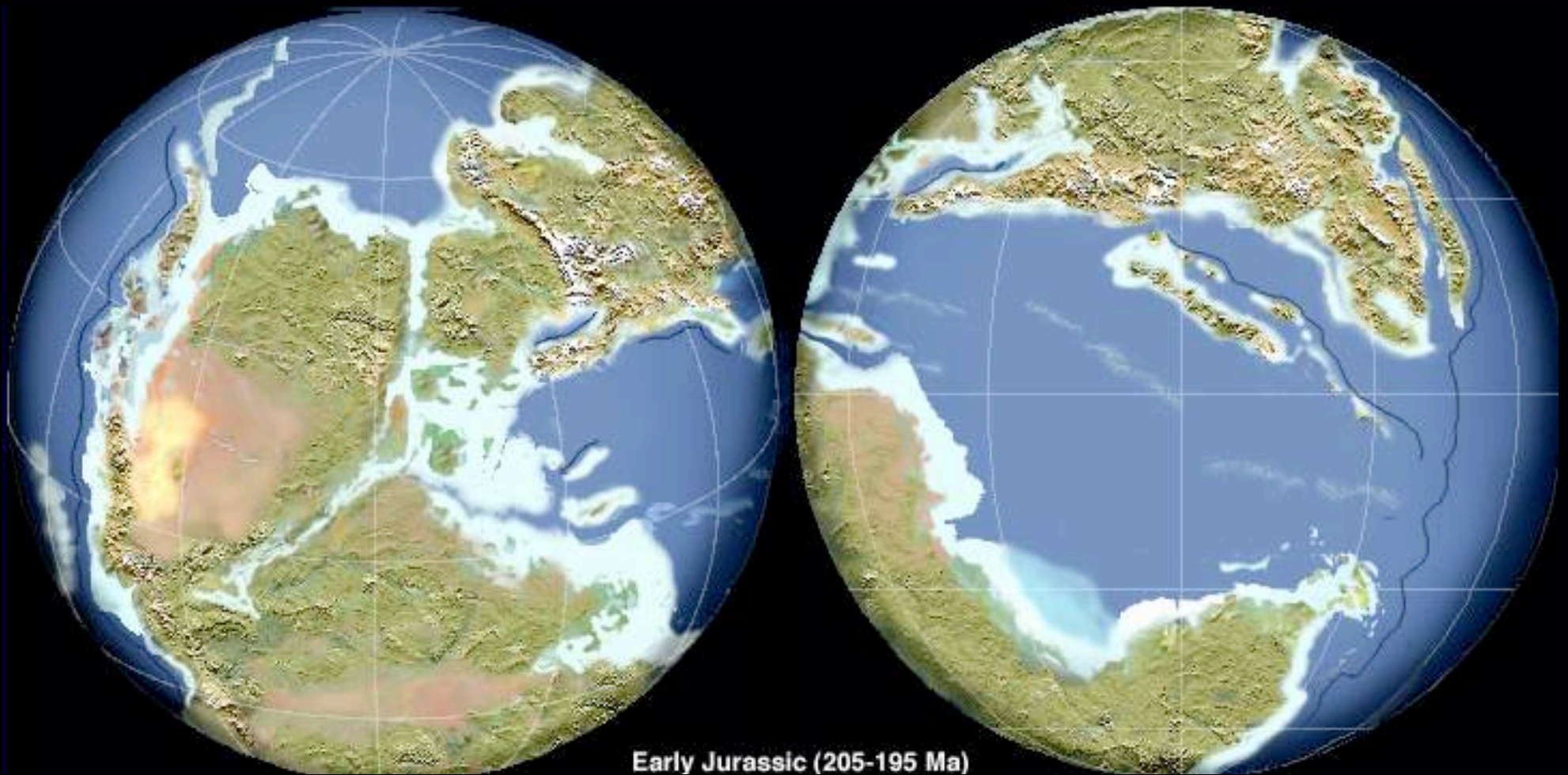


Mesozoic - Pangaea forms and breaks up



Early Jurassic (205-195 Ma)

Extinct Land Plants - the Fossil Record

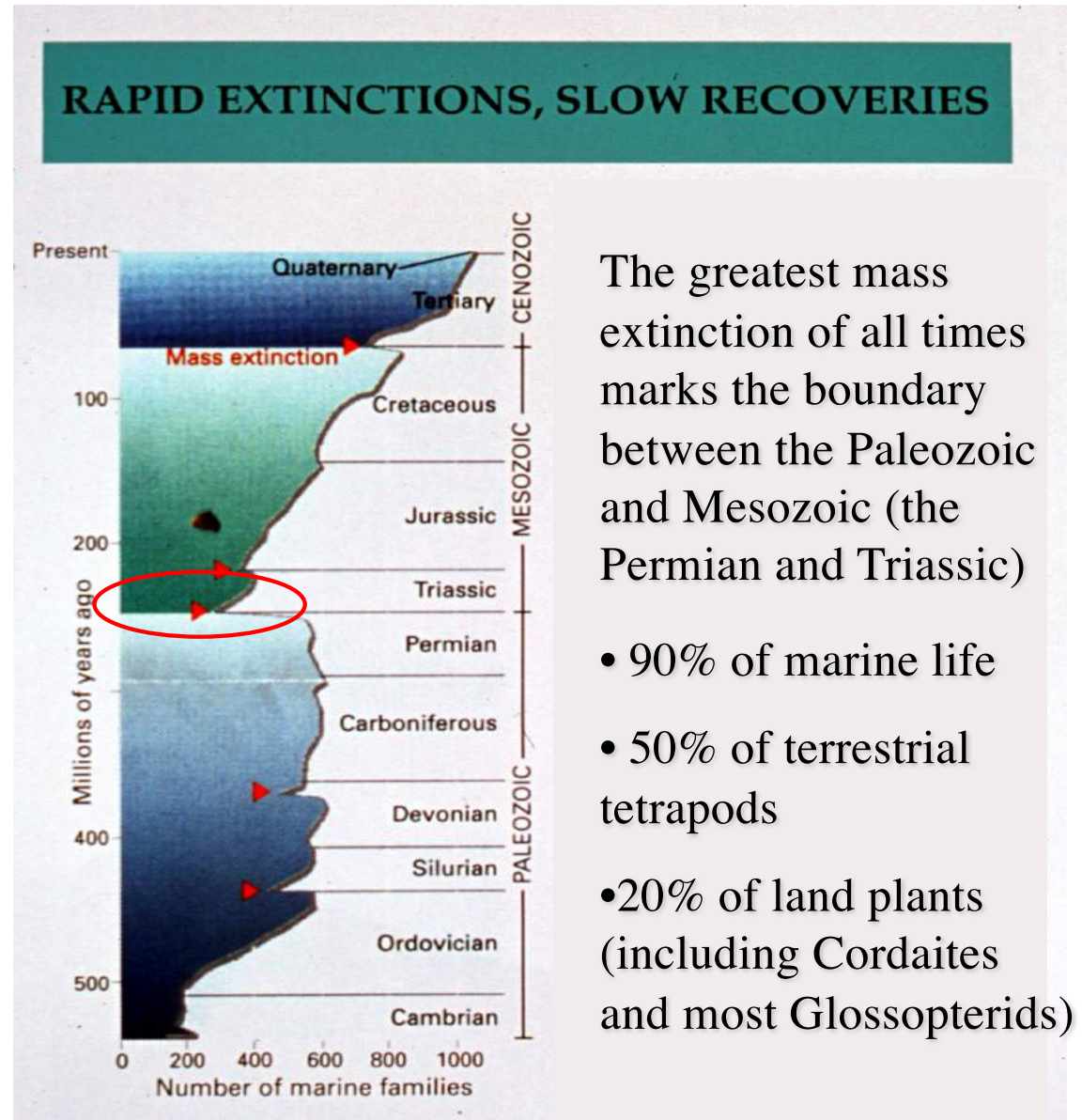
EON	ERA	PERIOD		EPOCH	MYA		
PHANEROZOIC	CENOZOIC	QUATERNARY		RECENT	0.01	← ICE AGE ENDS	
				PLEISTOCENE	1.6	← ICE AGE BEGINS EARLIEST HUMANS	
		TERTIARY	NEOGENE	PLIOCENE	5.3		
				MIOCENE	23.7		
			PALEOGENE	OLIGOCENE	36.6		
				EOCENE	57.8	← FORMATION OF HIMALAYAS	
				PALEOCENE	66	← DINOSAUR EXTINCTION ROCKY MTS. FORMED	
			MESOZOIC	CRETACEOUS	144	←	
				JURASSIC	208		FIRST MAMMALS PANGEA BREAK UP FIRST DINOSAURS
	TRIASSIC	245		←			
	PERMIAN	286					
	PENNSYLVANIAN	320		←	FIRST REPTILES		
	MISSISSIPPIAN	360		←	FIRST AMPHIBIANS		
	DEVONIAN	408					
	SILURIAN	438		←	FIRST LAND PLANTS		
	ORDOVICIAN	505		←	FIRST FISH		
	PALEOZOIC	CAMBRIAN	570				
		PROTEZOIC EON		2500	←	EARLIEST SHELLED ANIMALS	
		ARCHEAN EON		3800	←	EARLIEST FOSSIL RECORDED OF LIFE	
		4600					

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

EON	ERA	PERIOD		EPOCH
PHANEROZOIC	CENOZOIC	QUATERNARY		RECENT
				PLEISTOCENE
		TERTIARY	NEOGENE	PLIOCENE
				MIOCENE
			PALEOGENE	OLIGOCENE
				EOCENE
				PALEOCENE
			MESOZOIC	CRETACEOUS
	JURASSIC			208
	TRIASSIC			245
	PALEOZOIC	PERMIAN		286
		PENNSYLVANIAN		320
		MISSISSIPPIAN		360
		DEVONIAN		408
		SILURIAN		438
		ORDOVICIAN		505
		CAMBRIAN		570
		PRECAMBRIAN	PROTEZOIC EON	
ARCHEAN EON			3800	
				4600



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*).

Dinosaurs arose in the late Triassic from thecodont reptiles.

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



Extinct Land Plants - the Fossil Record

Triassic Period (245 - 208 mya)



Plateosaurus (larger) spies two *Yaleosaurus* (left) and a smaller *Coelophysis* 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 araucana - 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

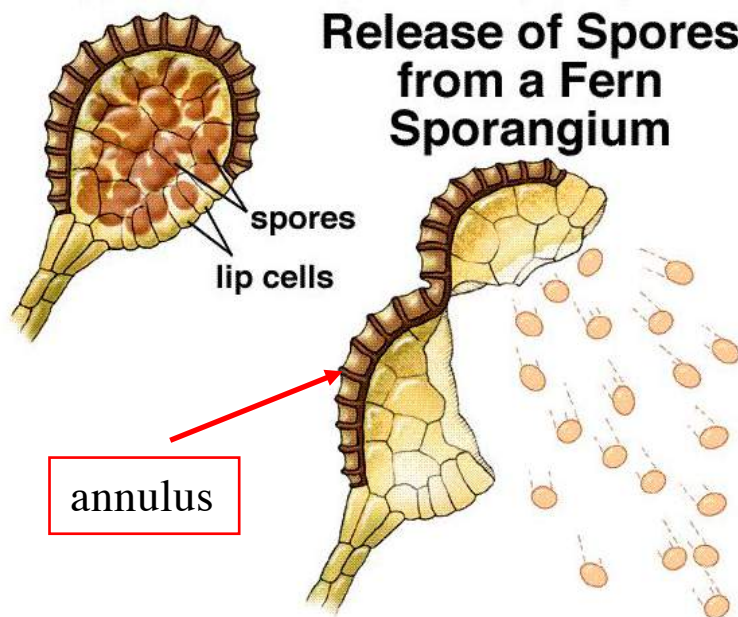
Extinct Land Plants - the Fossil Record

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:



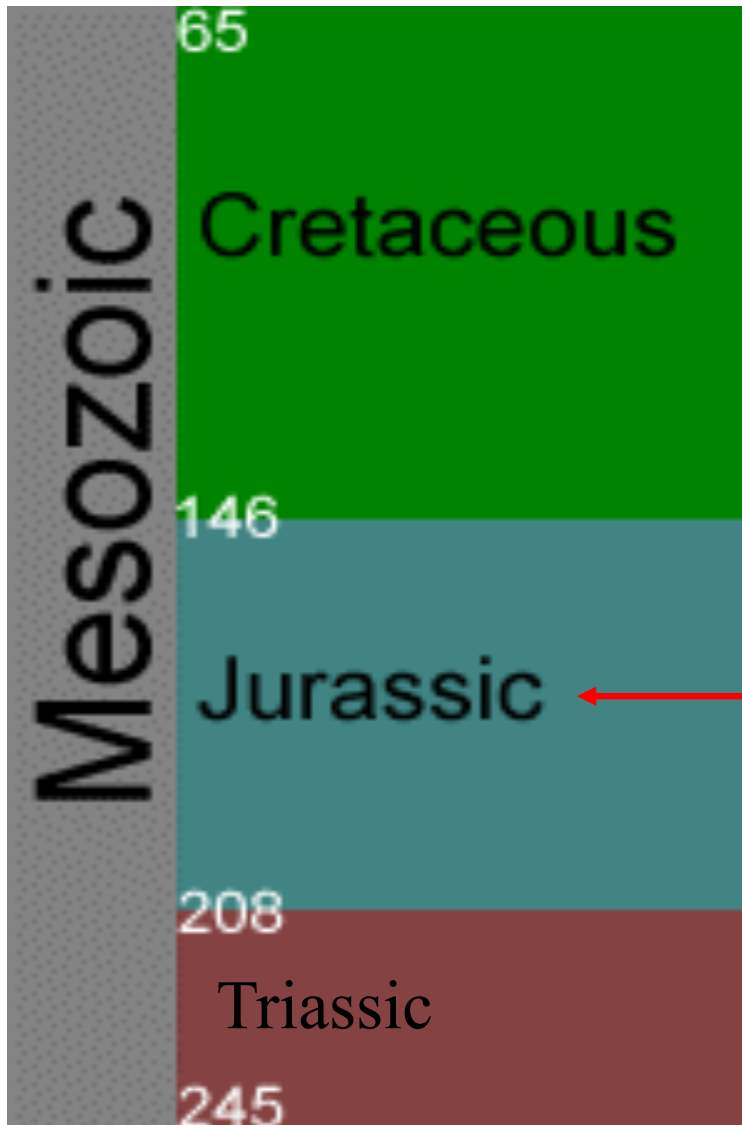
Osmundaceae -
cinnamon fern

Cyathaceae - tree fern



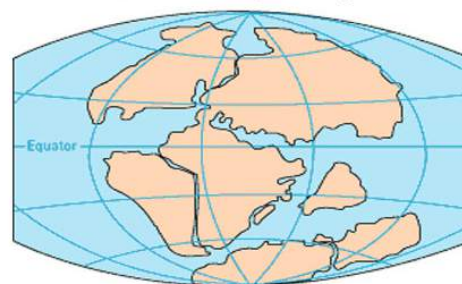
Schizaceaceae -
climbing fern

Extinct Land Plants - the Fossil Record

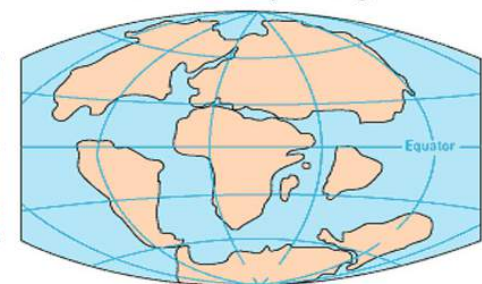


Jurassic Period (208 - 146mya)

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



Jurassic



Cretaceous



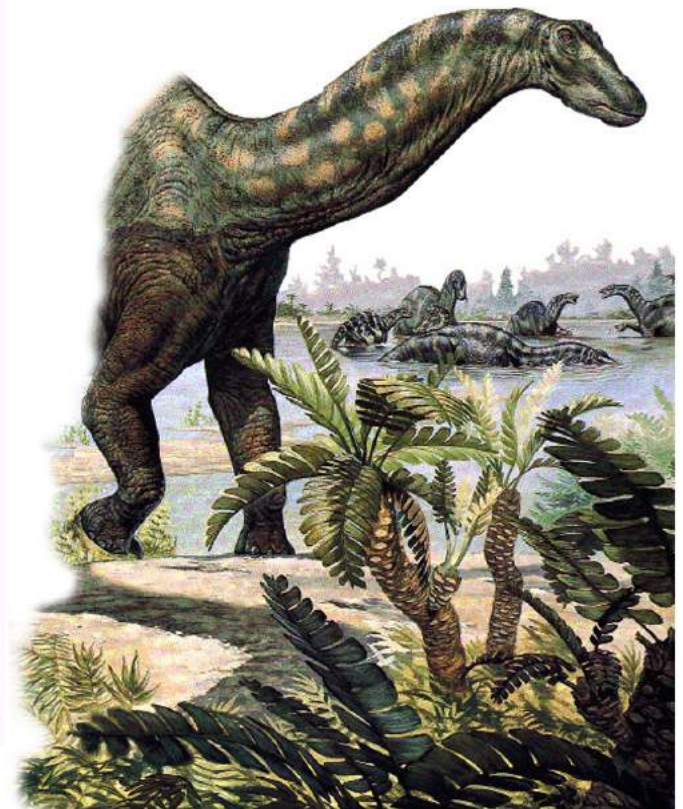
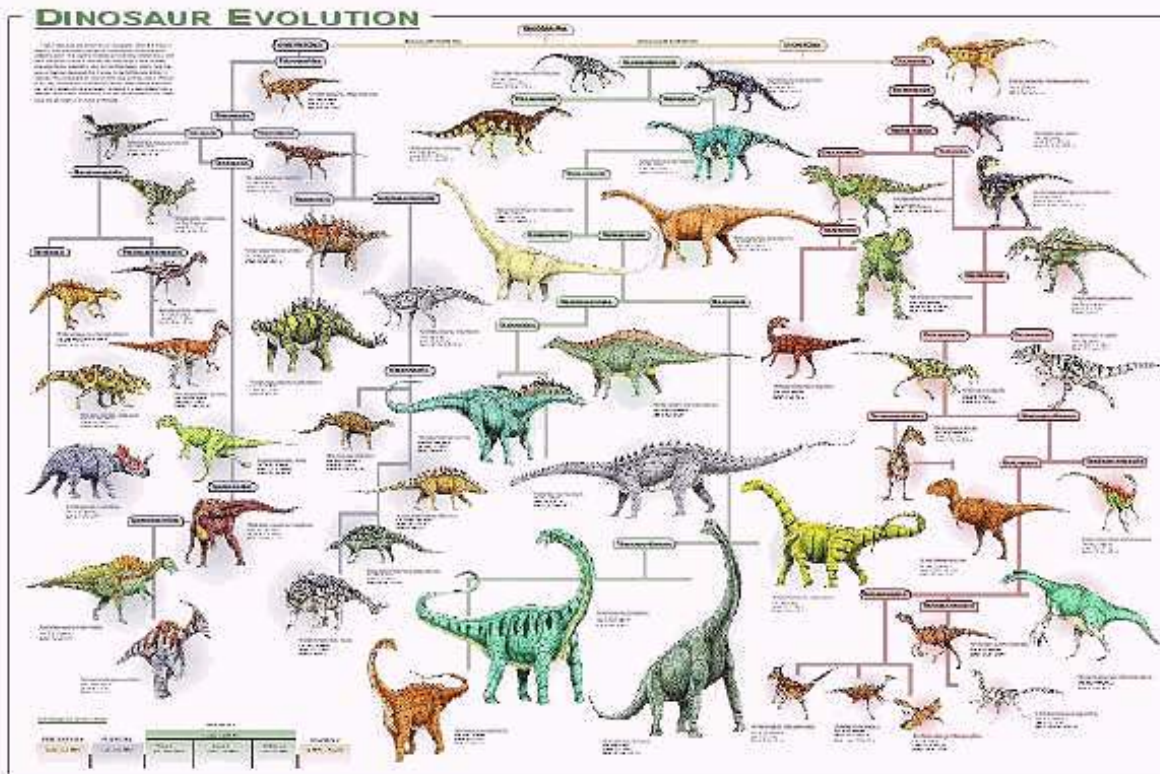
Present

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)



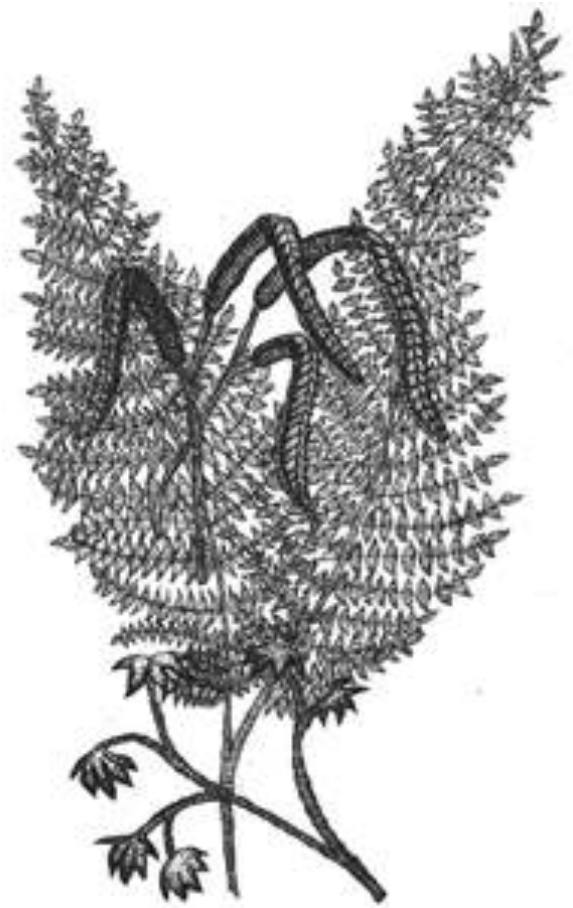
Extinct Land Plants - the Fossil Record

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

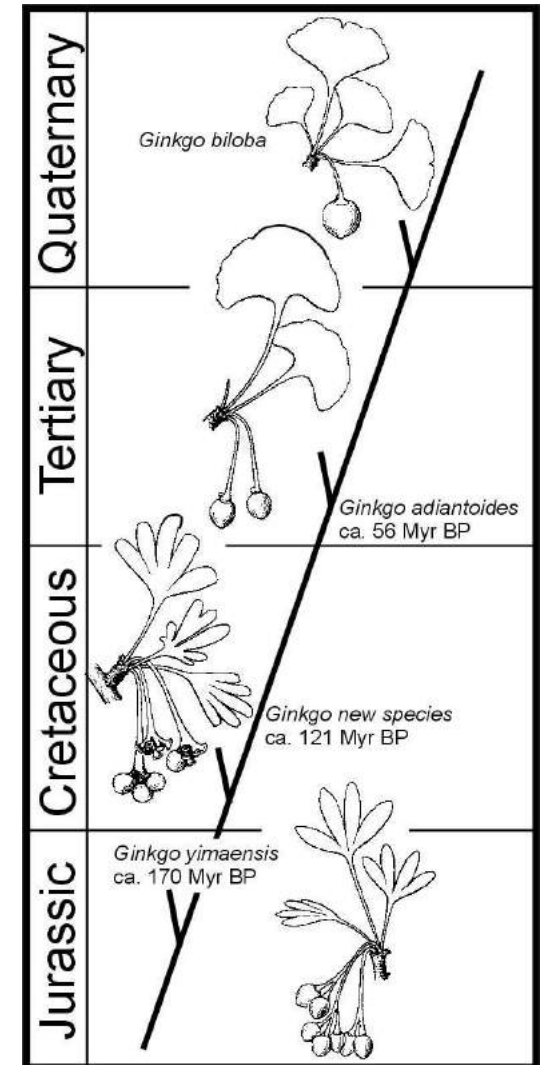


Jurassic Period (208 - 146mya)

“Modern” genera are first seen for *Ginkgo* . . .



John N. Agnew ©2000



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

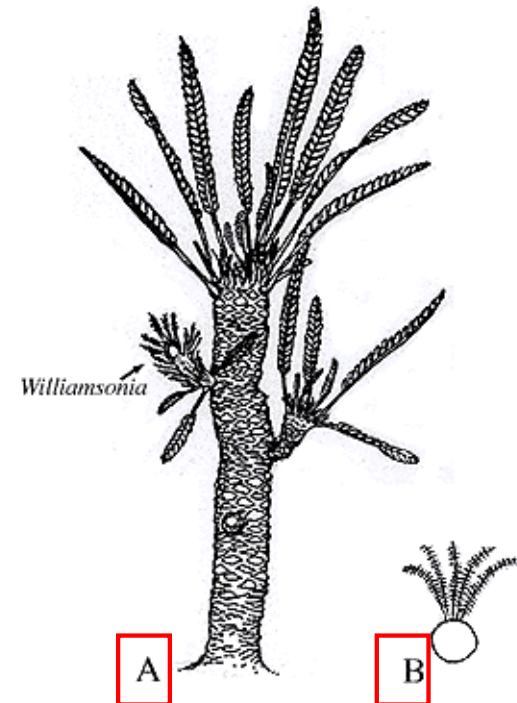
Jurassic Period (208 - 146mya)

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*

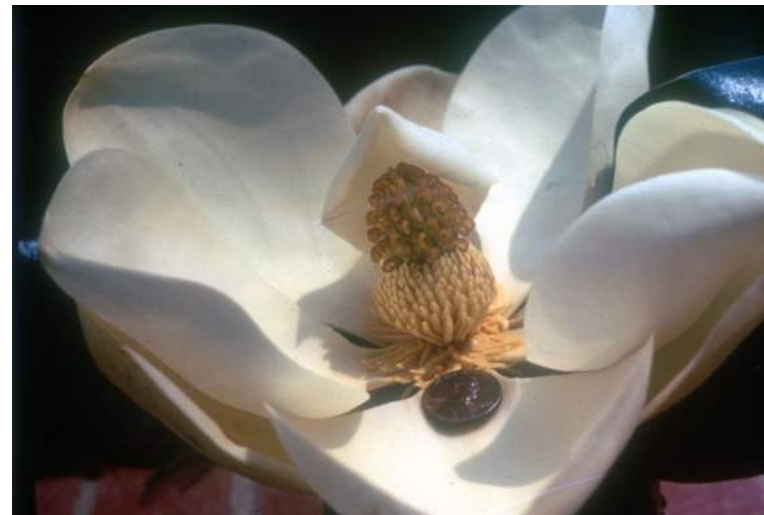
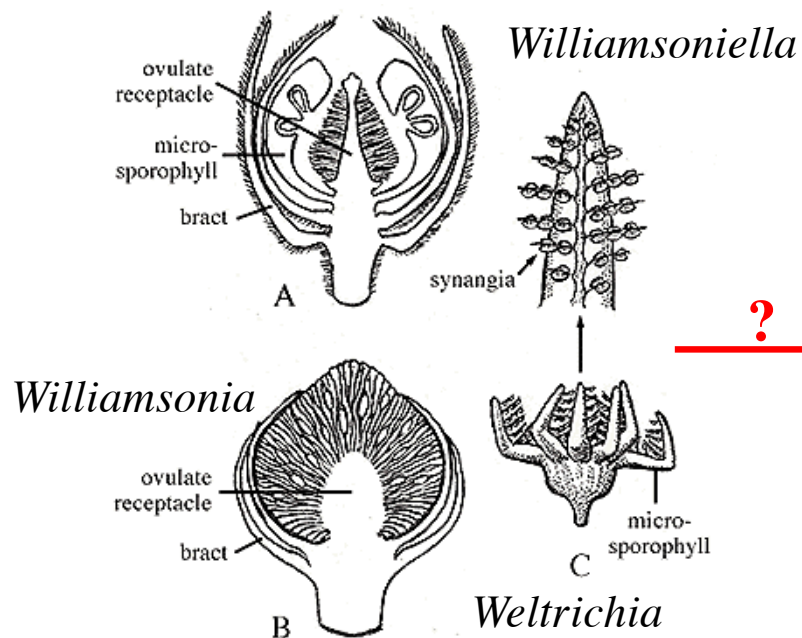


Extinct Land Plants - the Fossil Record

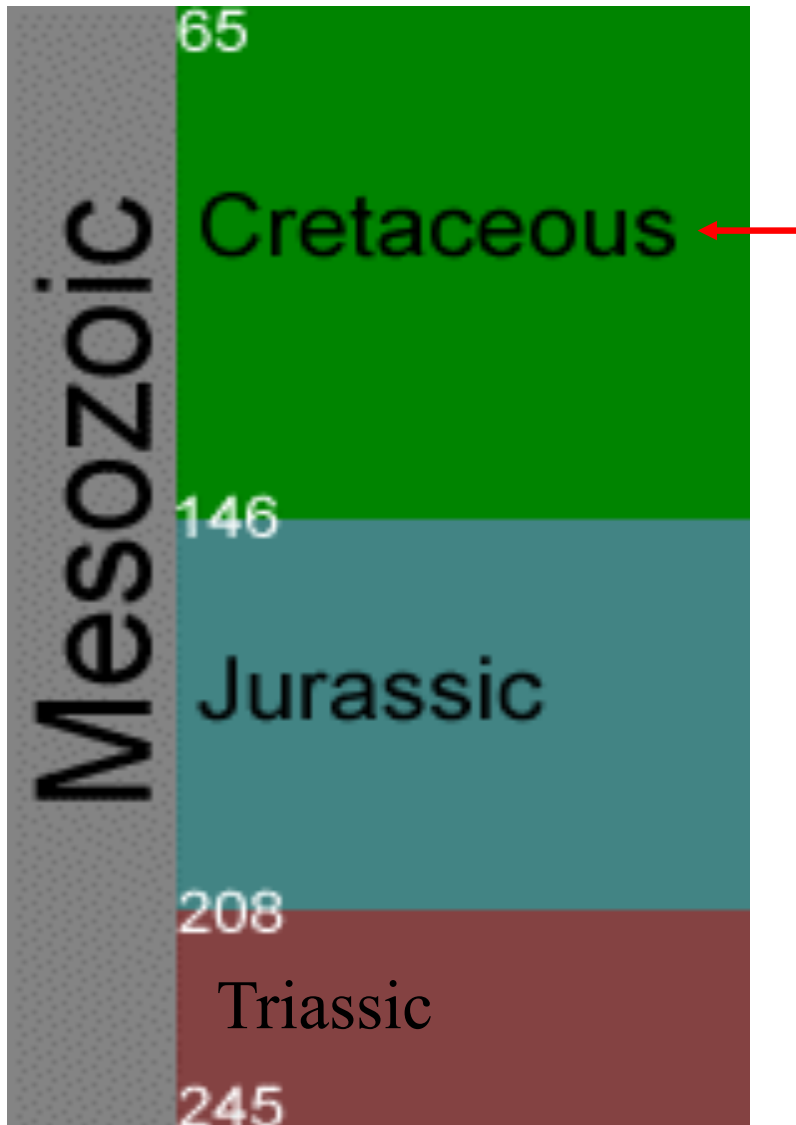
Jurassic Period (208 - 146mya)

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



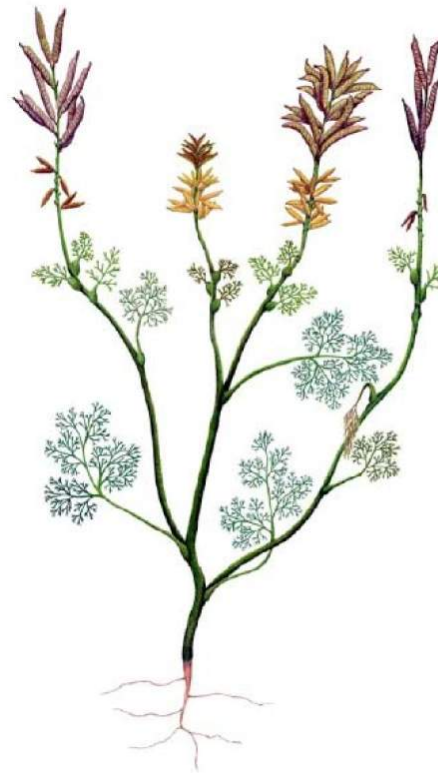
Extinct Land Plants - the Fossil Record

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

The earliest fossils to date
come from 127 mya in
China



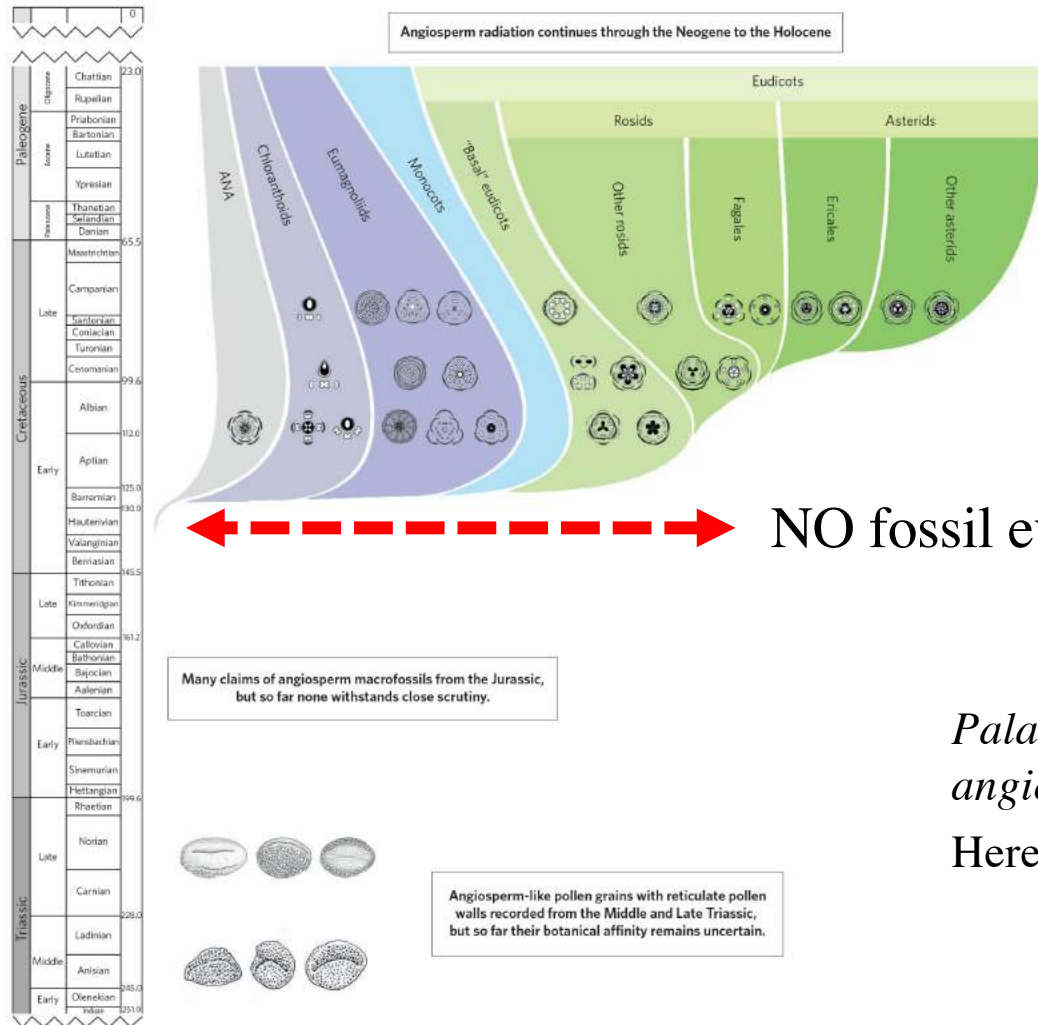
Archeafructus reconstruction



Fossil *Archeafructus*

Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)



← NO fossil evidence of flowering plants in Jurassic →

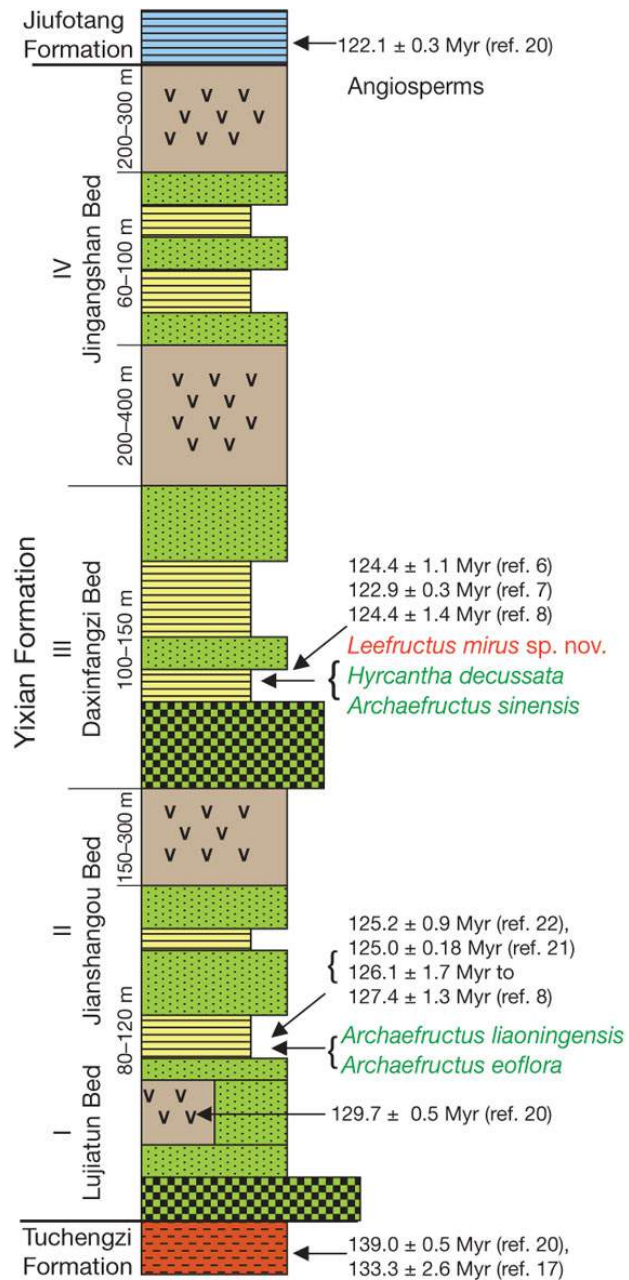
Palaeobotanical redux: revisiting the age of the angiosperms

Herendeen et al. 2017. *Nature Plants*

Figure 1 | Fossil ranges of major angiosperm lineages, focused on the Cretaceous diversification. The fossil record of plant micro-, meso- and

Extinct Land Plants - the Fossil Record

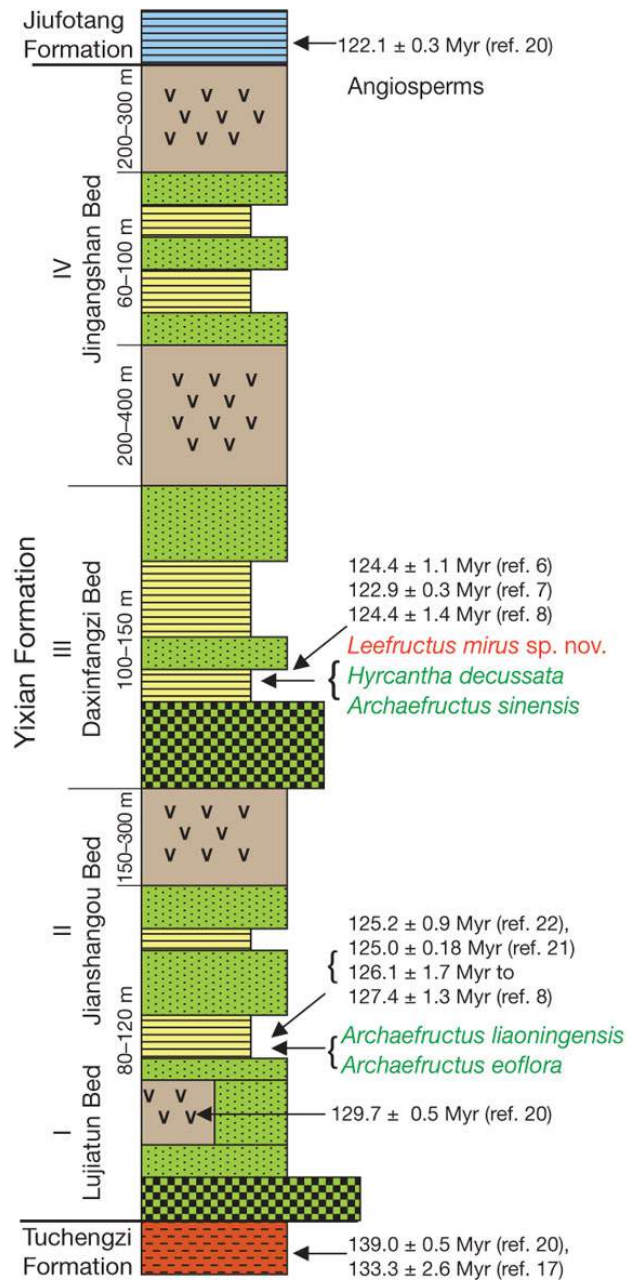
Cretaceous Period (146 - 65 mya)



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

Extinct Land Plants - the Fossil Record

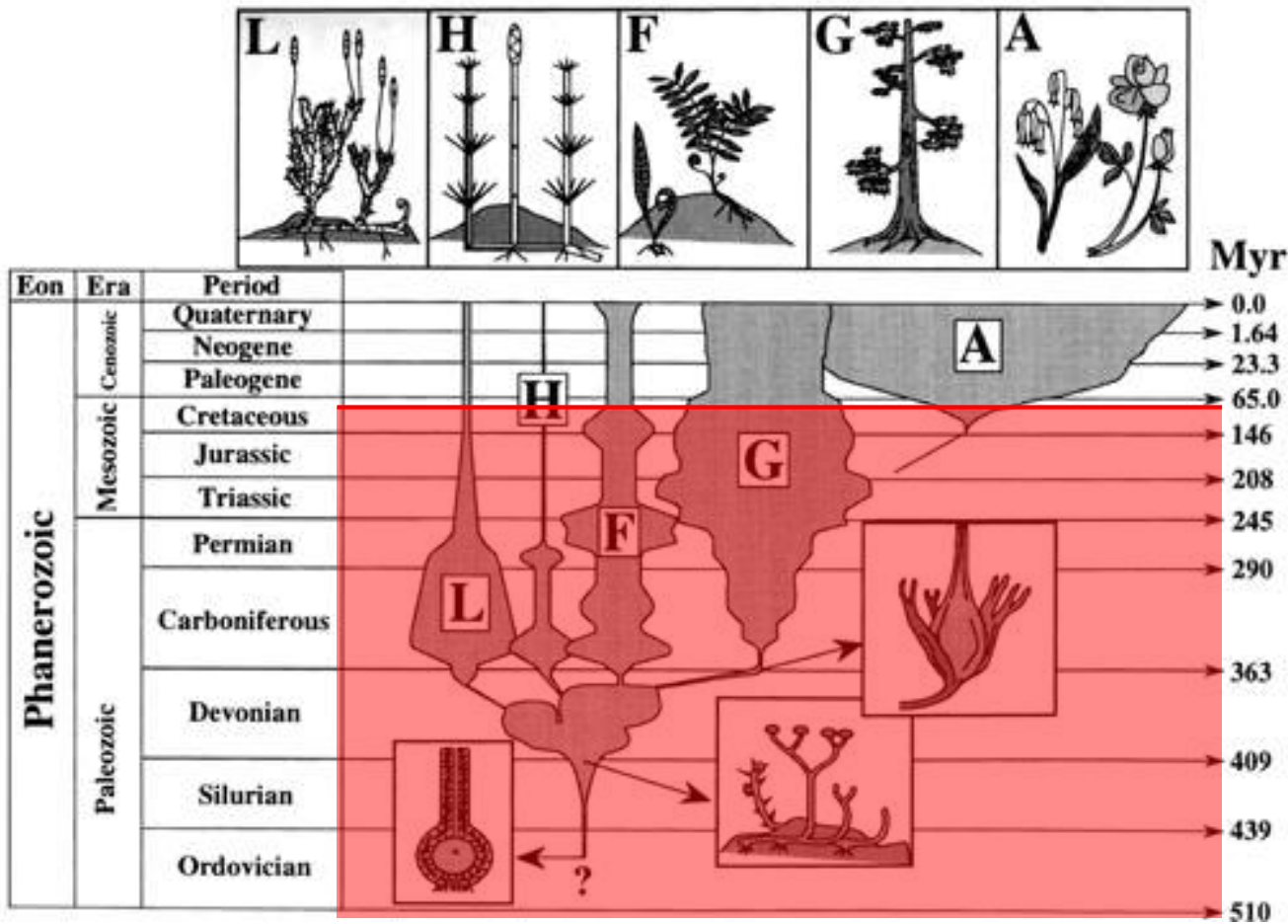
Cretaceous Period (146 - 65 mya)



Archaeofructus and *Leefructus*
-the rise of Angiosperms

Extinct Land Plants - the Fossil Record

Cretaceous Period (146 - 65 mya)

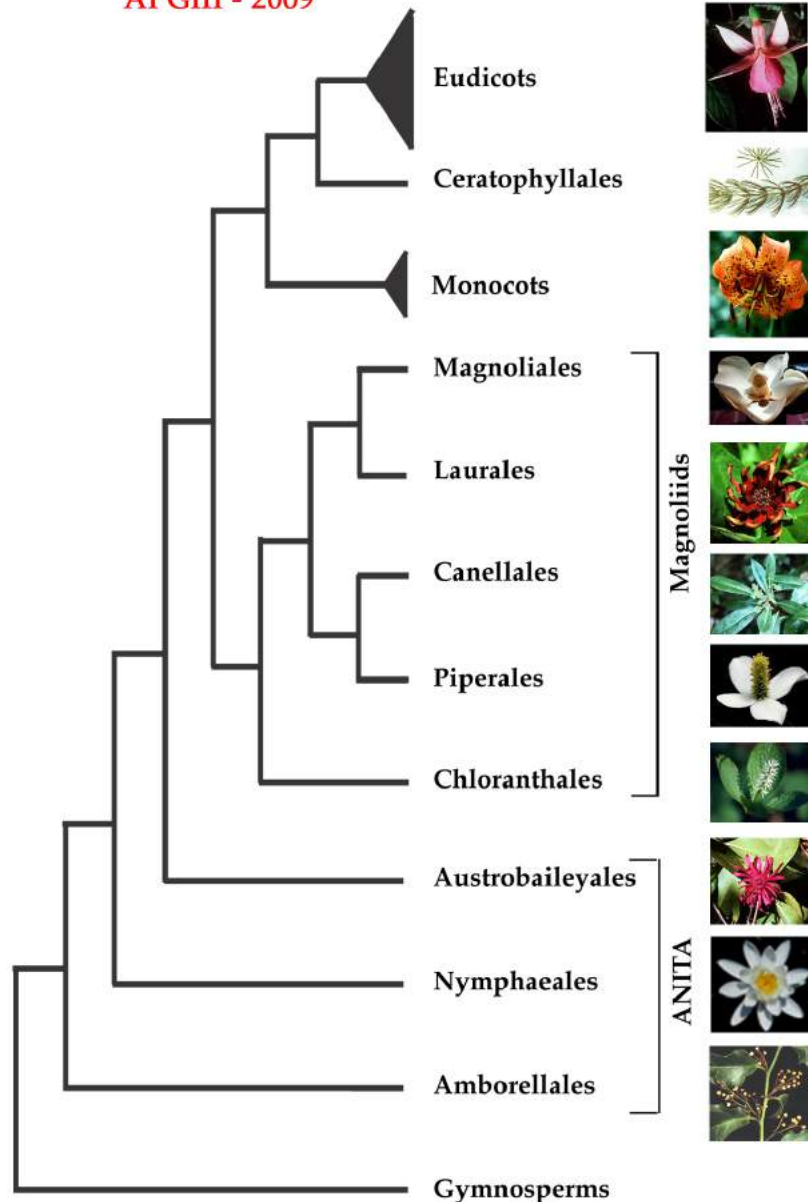


All lineages of land plants have thus made their appearance by the Cretaceous

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

Basal Angiosperm Phylogeny
APGIII - 2009



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

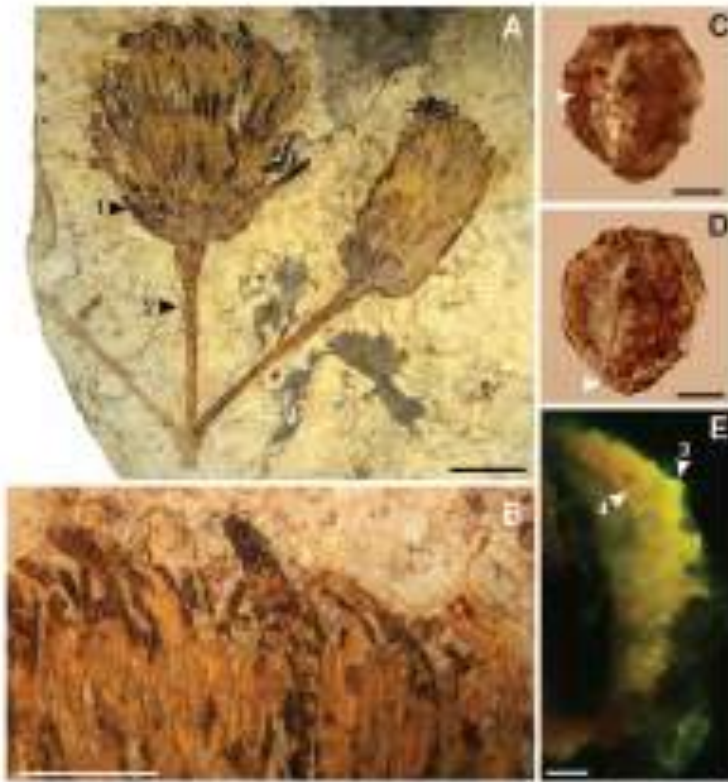


Extinct Land Plants - the Fossil Record

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



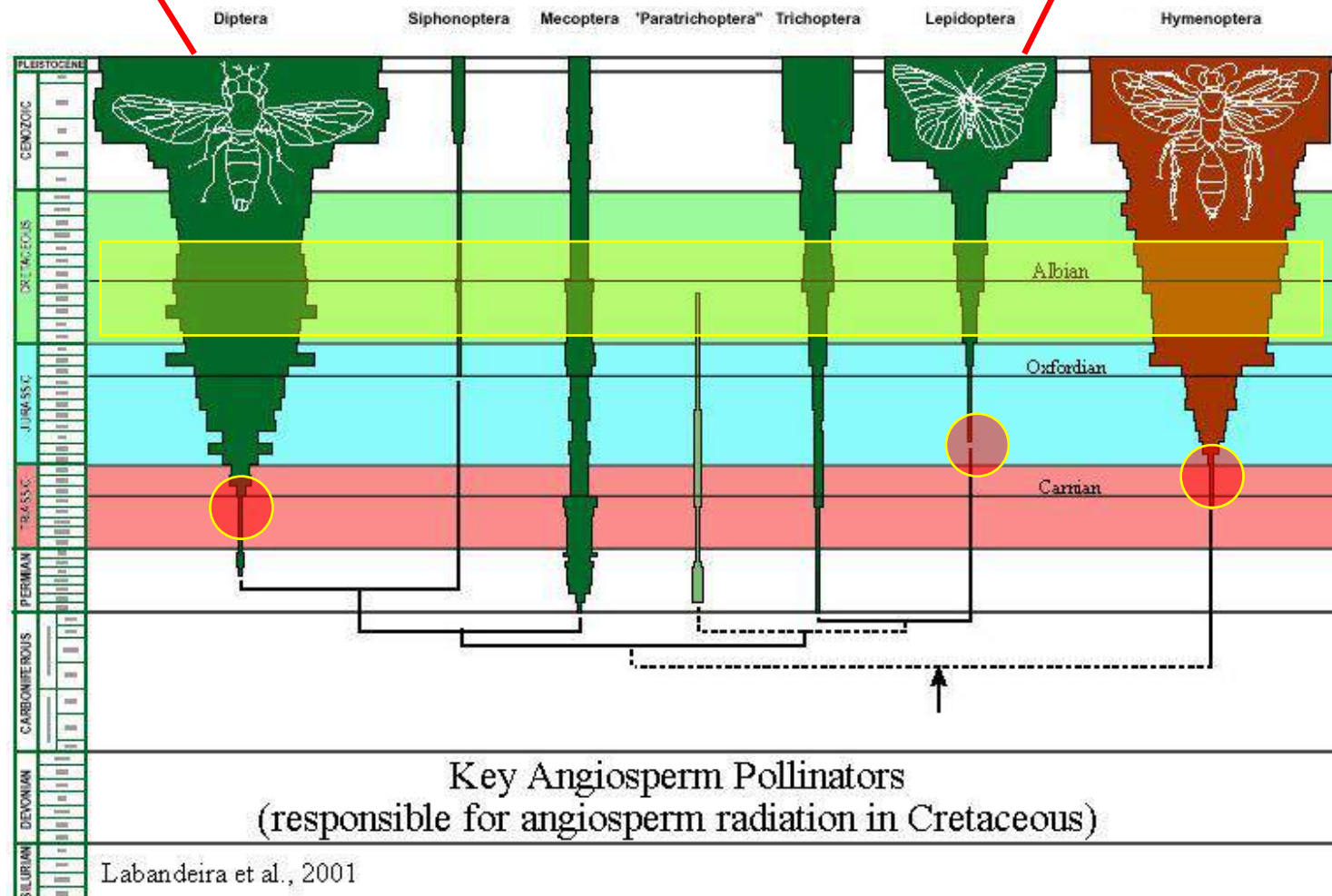
Eocene Patagonia Fossils of the Daisy Family

V. D. Barreda,^{1,2*} L. Palazzesi,^{1,2} M. C. Tellería,^{2,3,4} L. Katinas,^{2,5} J. V. Crisci,^{2,3,5} K. Bremer,⁶
M. G. Passalia,^{2,7} R. Corsolini,⁶ R. Rodríguez Brizuela,¹ F. Bechis^{2,9}

Science, 2010

A close-up photograph of a butterfly with grey wings and orange spots feeding on a yellow flower. The butterfly is positioned in the center of the frame, with its wings spread. The flower is bright yellow and has a red center. The background is a soft, out-of-focus green.

A close-up photograph of a bee, likely a bumblebee, perched on a small white flower. The bee's body is covered in yellow and black stripes, and its wings are translucent. The background is a soft-focus green, suggesting foliage.



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

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



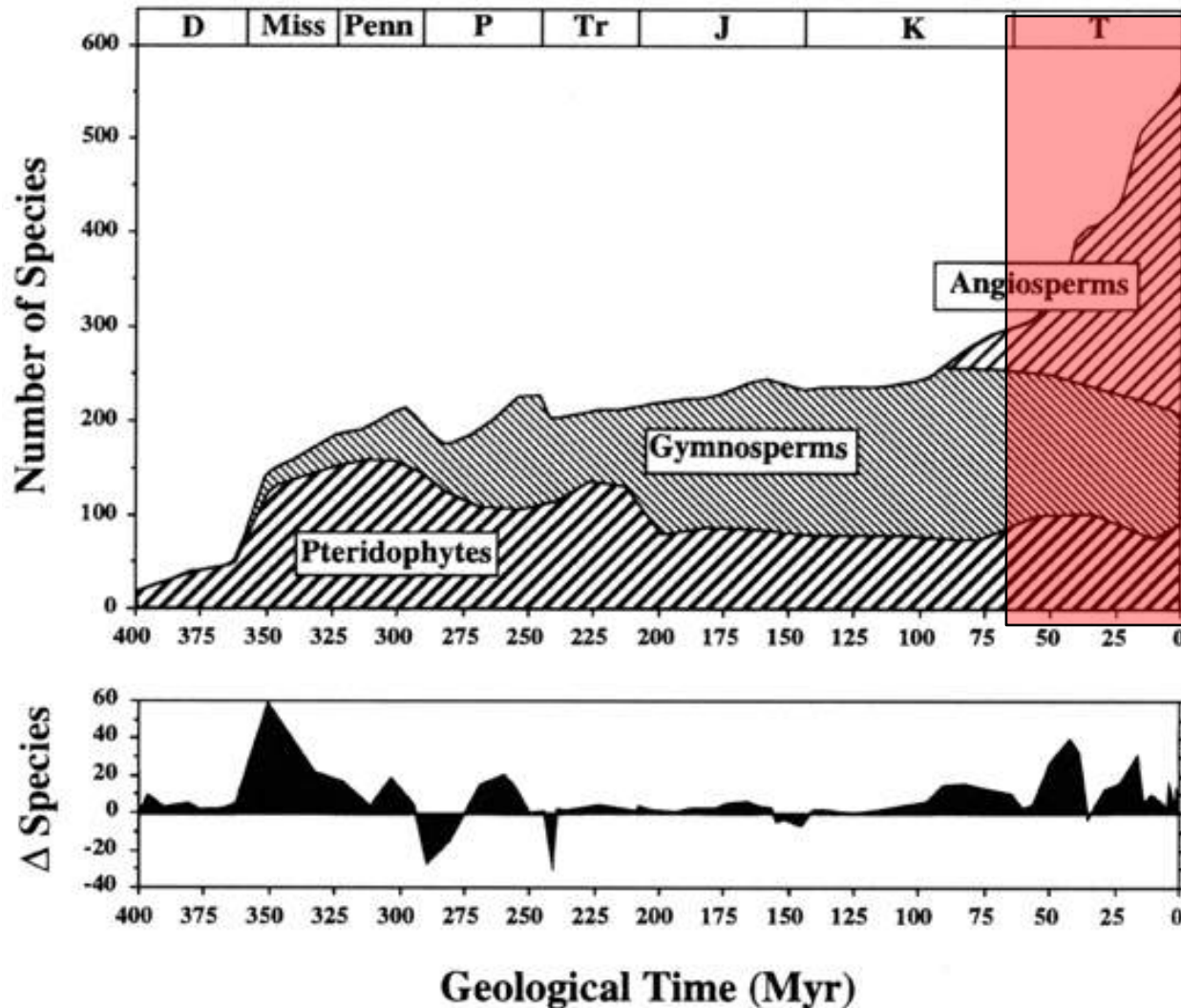
and birds

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

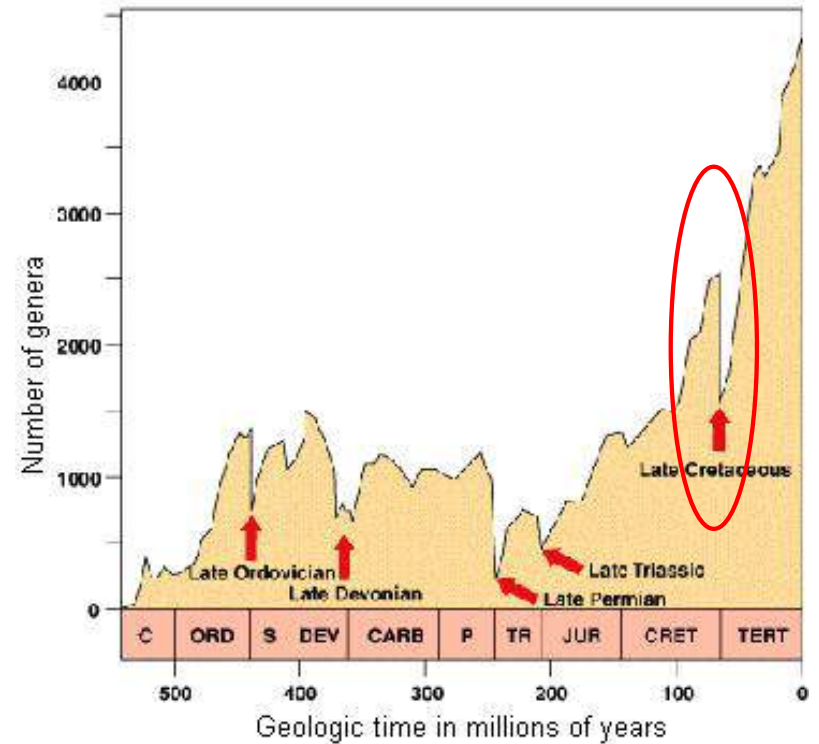
Extinct Land Plants - the Fossil Record

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



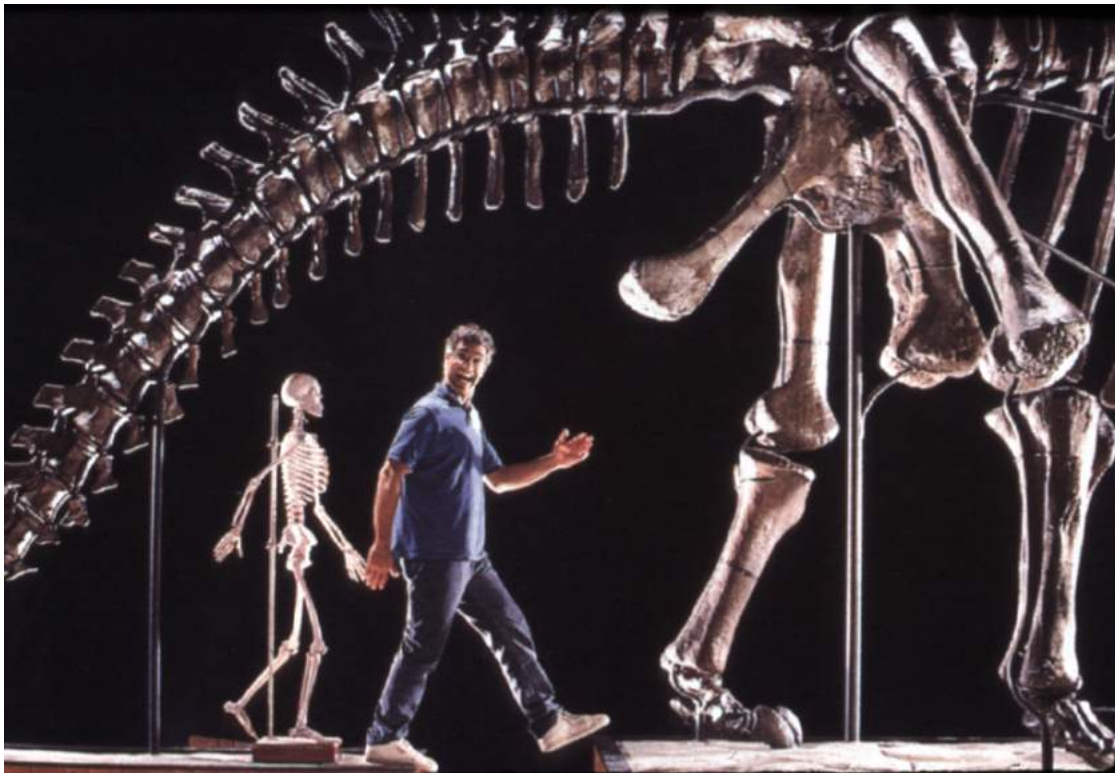
Apatosaurus & Homo



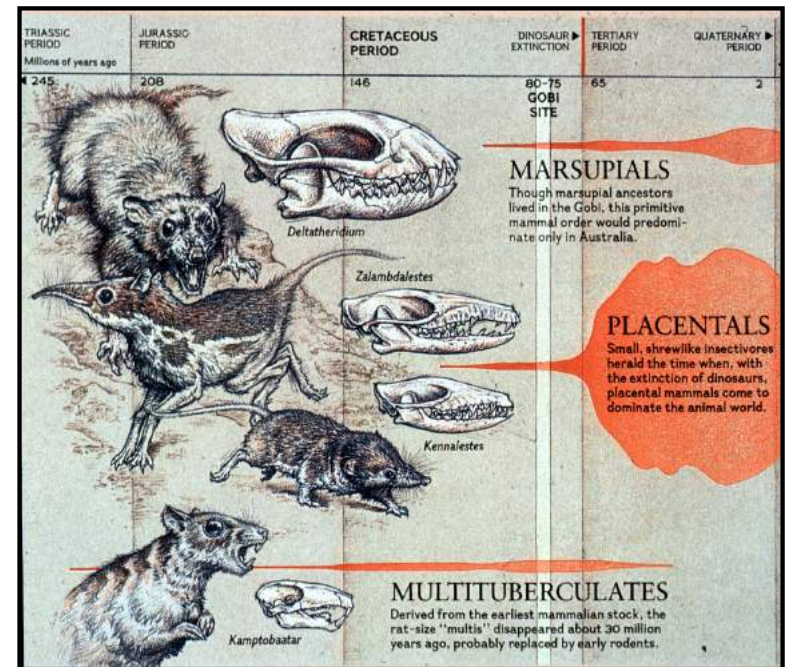
Extinct Land Plants - the Fossil Record

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



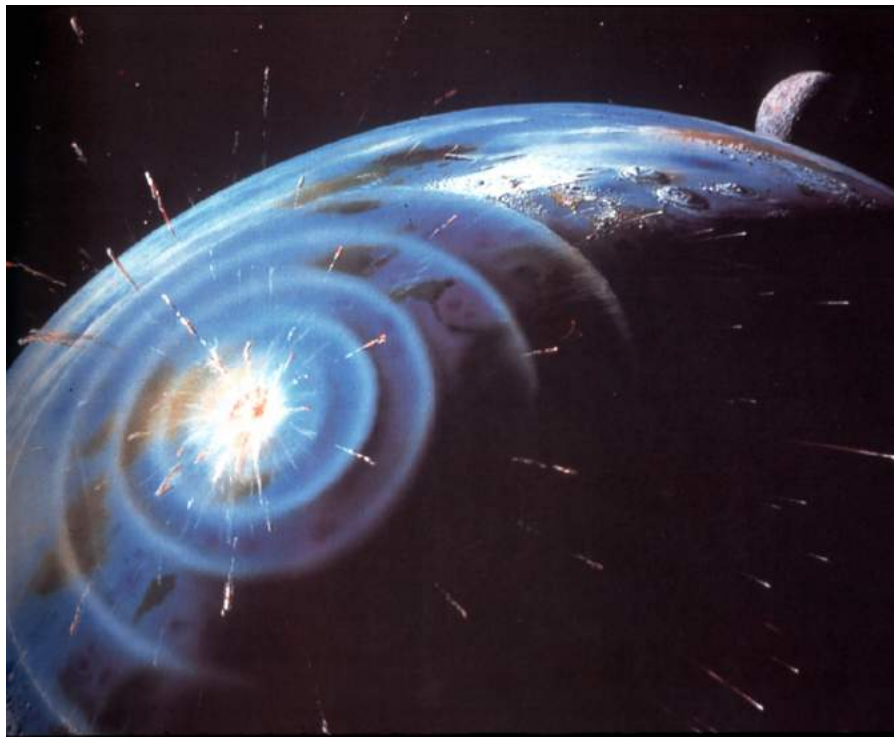
Apatosaurus & Homo



Extinct Land Plants - the Fossil Record

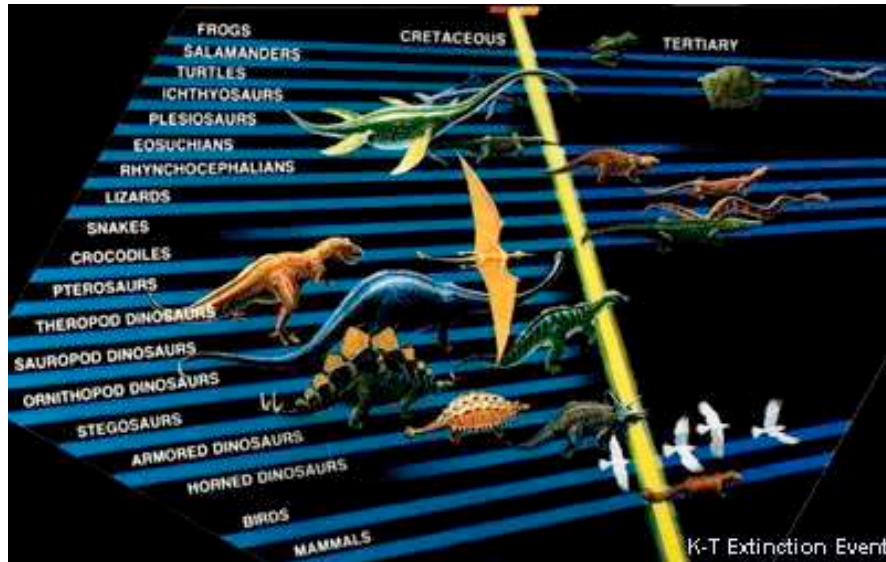
Cretaceous Period (146 - 65 mya)

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

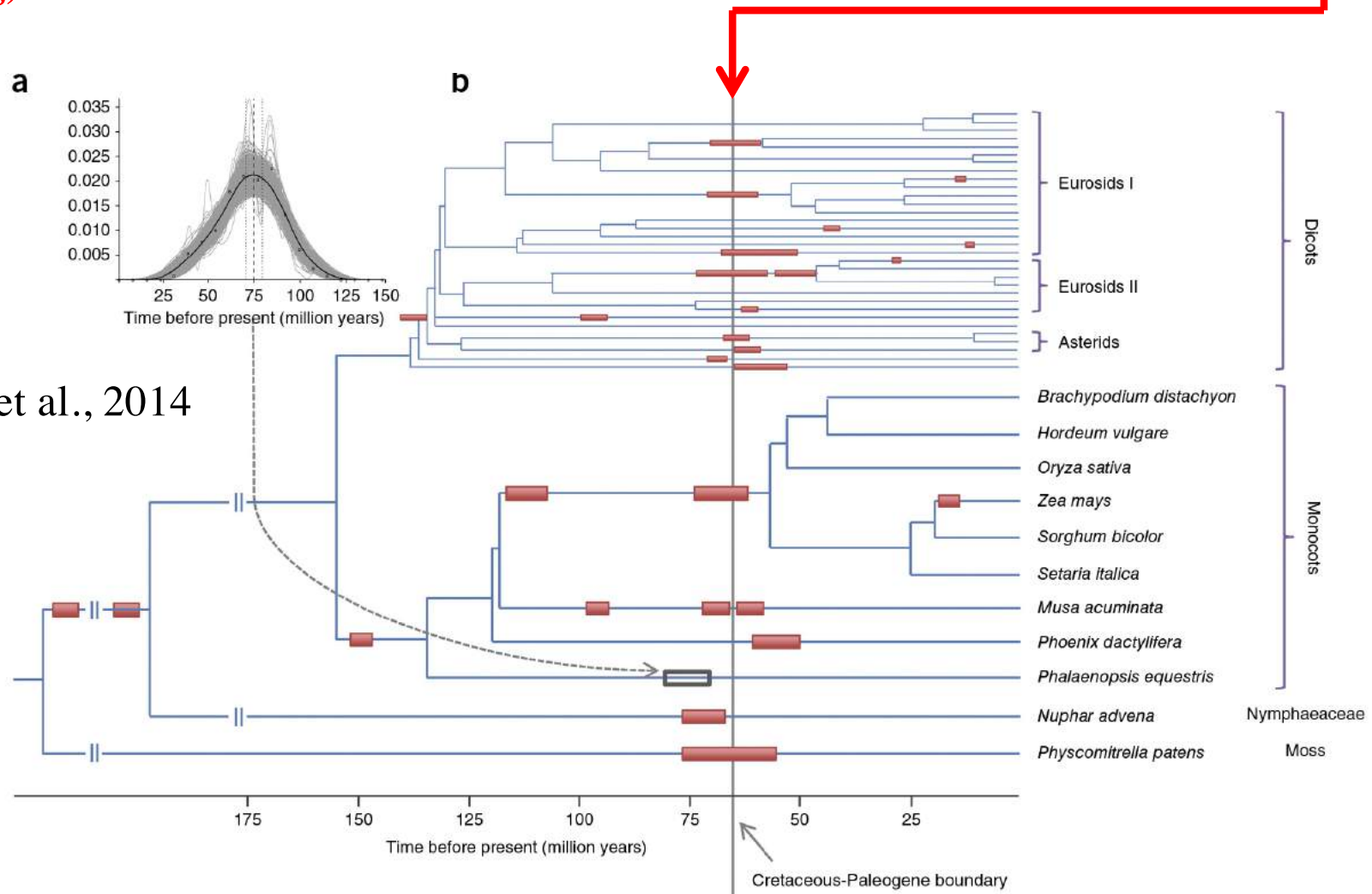
Kevin Vanneste^{1,2}, Steven Maere^{1,2} and Yves Van de Peer^{1,2,3}



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*

