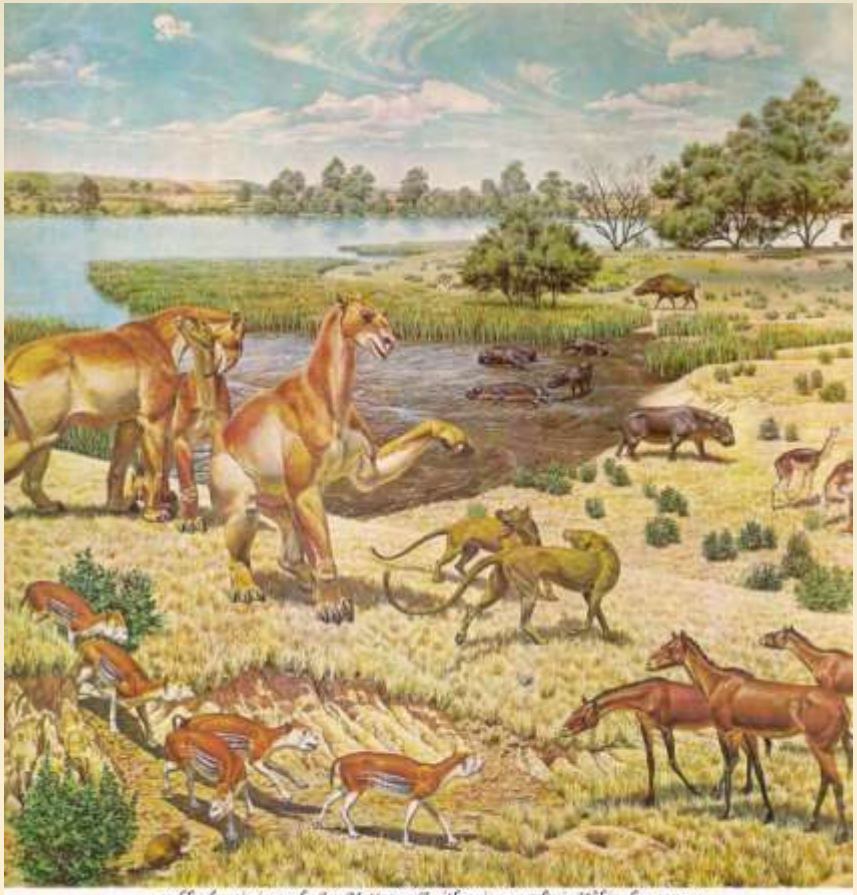
# Cenozoic Era





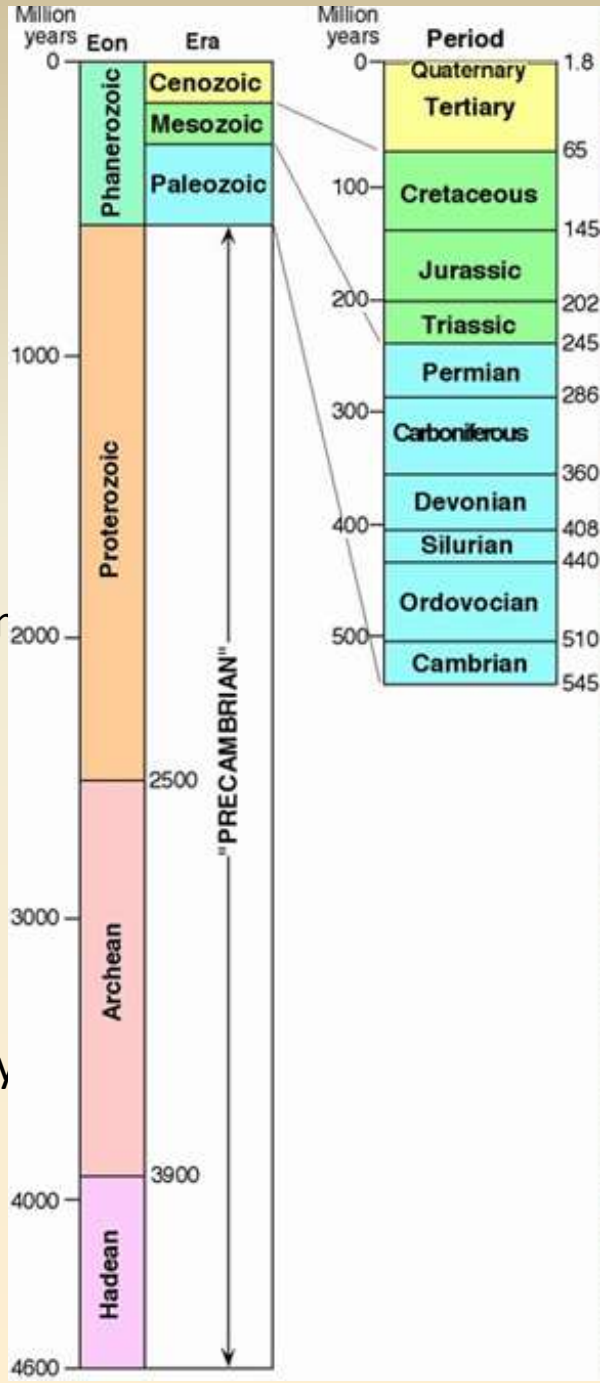
# Geological Eras

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.

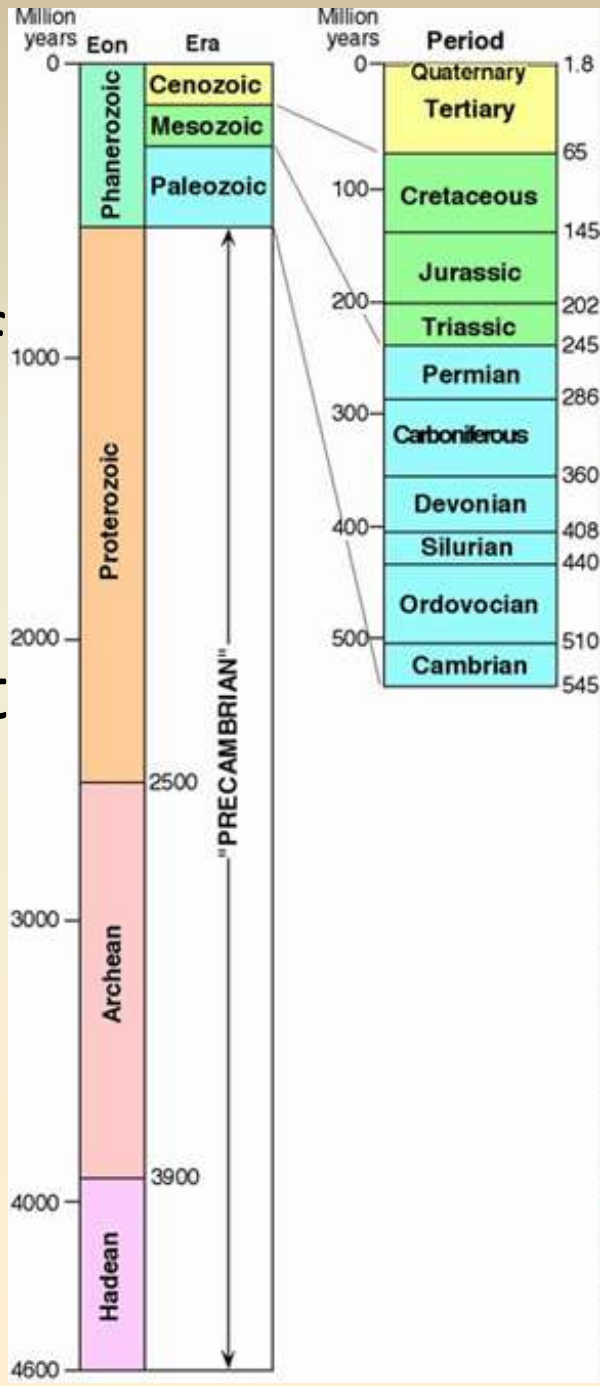


# Geological Eras

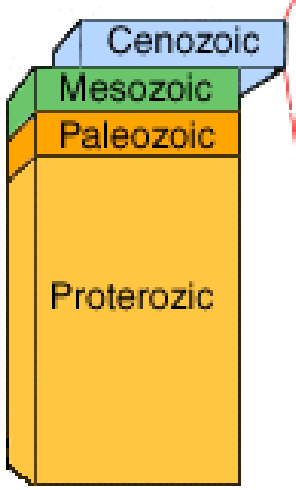
Paleozoic Era. 550 to 250 million years ago. Fossils appear, complex multicellular organisms, invasion of the land by plants and animals.

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.



# Cenozoic

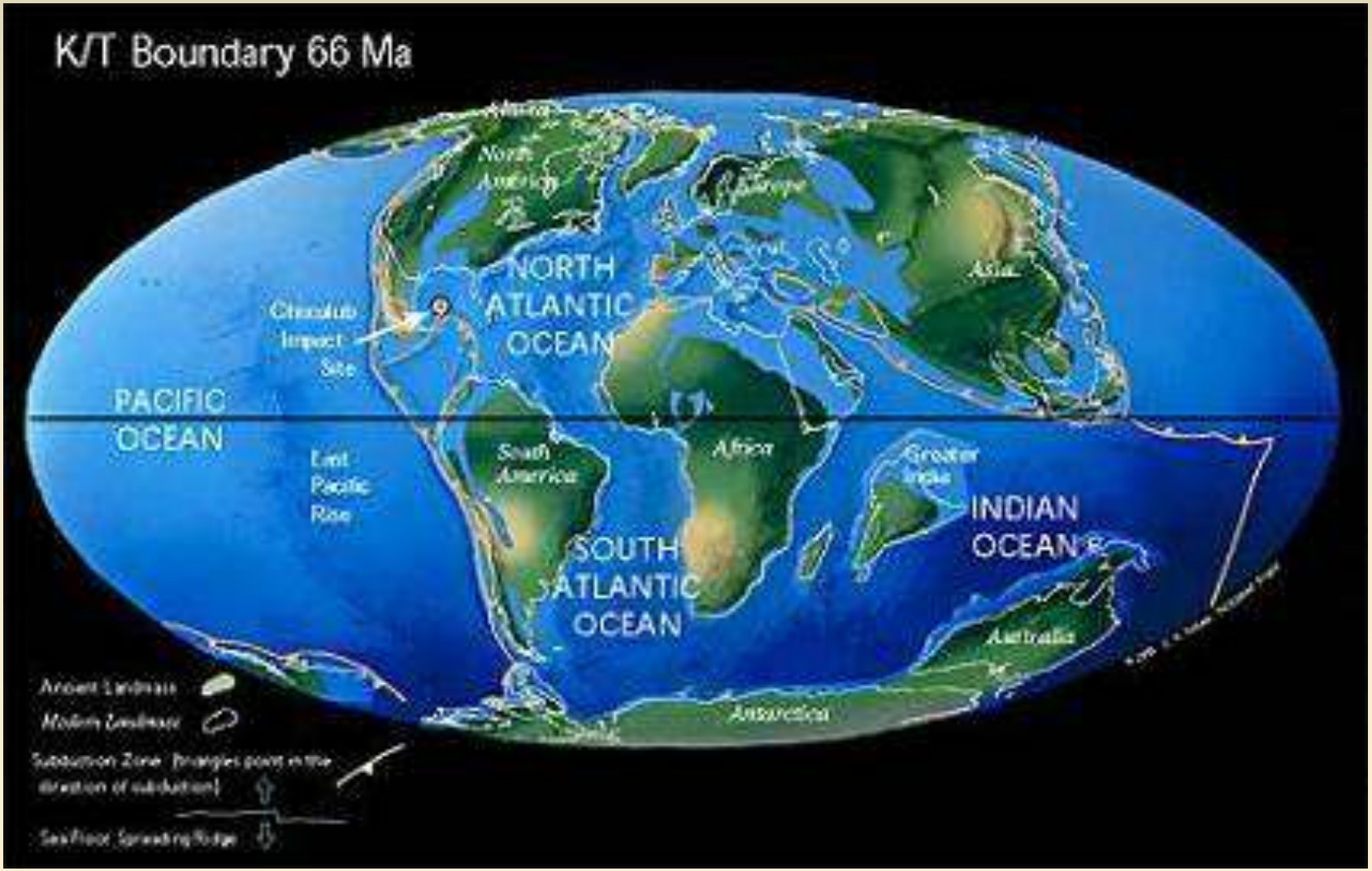



| PERIOD | EPOCH | PLANT EVOLUTION | ANIMAL EVOLUTION |
|---|---|---|---|
| Quaternary | Recent | Increase of herbaceous plant | Appearance of Homo sapiens |
| | Pleistocene | Repeated glaciation leads to mass extinction | Repeated glaciation leads to mass extinction<br>First Homo |
| 2.5 | | | |
| Tertiary | Pilocene | Decline of forests, spread of grasslands | Appearance of hominids |
| | Miocene | | Appearance of first apes |
| | Oligocene | | All modern genera of mammals present |
| | Eocene | | In seas, bony fish abound |
| | Paleocene | Explosive radiation of flowering plants | Rise of mammals<br>First placental mammals |
| 65 | | | |

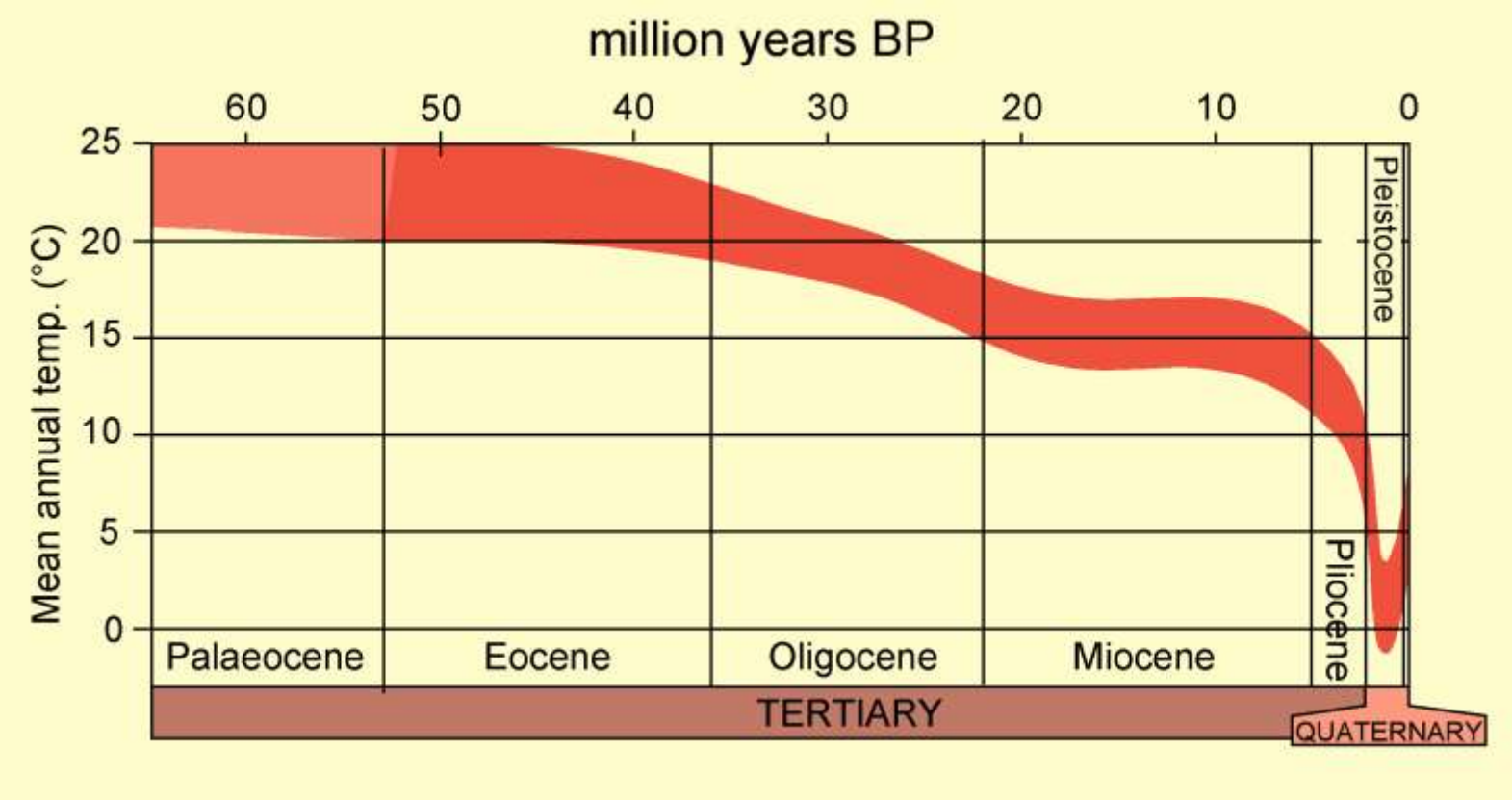
Millions of years ago

| Eon | Era | Period | | Epoch Start Date (mya) | |
|---|---|---|---|---|---|
| Phanerozoic | Cenozoic | Quaternary | | Holocene | 0.01 |
| | | | | Pleistocene | 1.64 |
| | | Tertiary | Neogene | Pliocene | 5.2 |
| | | | | Miocene | 23.3 |
| | | | Paleogene | Oligocene | 35.4 |
| | | | | Eocene | 56.5 |
| | | | | Paleocene | 65 |

Continents separated, isolated faunas evolve
India pushes up toward Asia

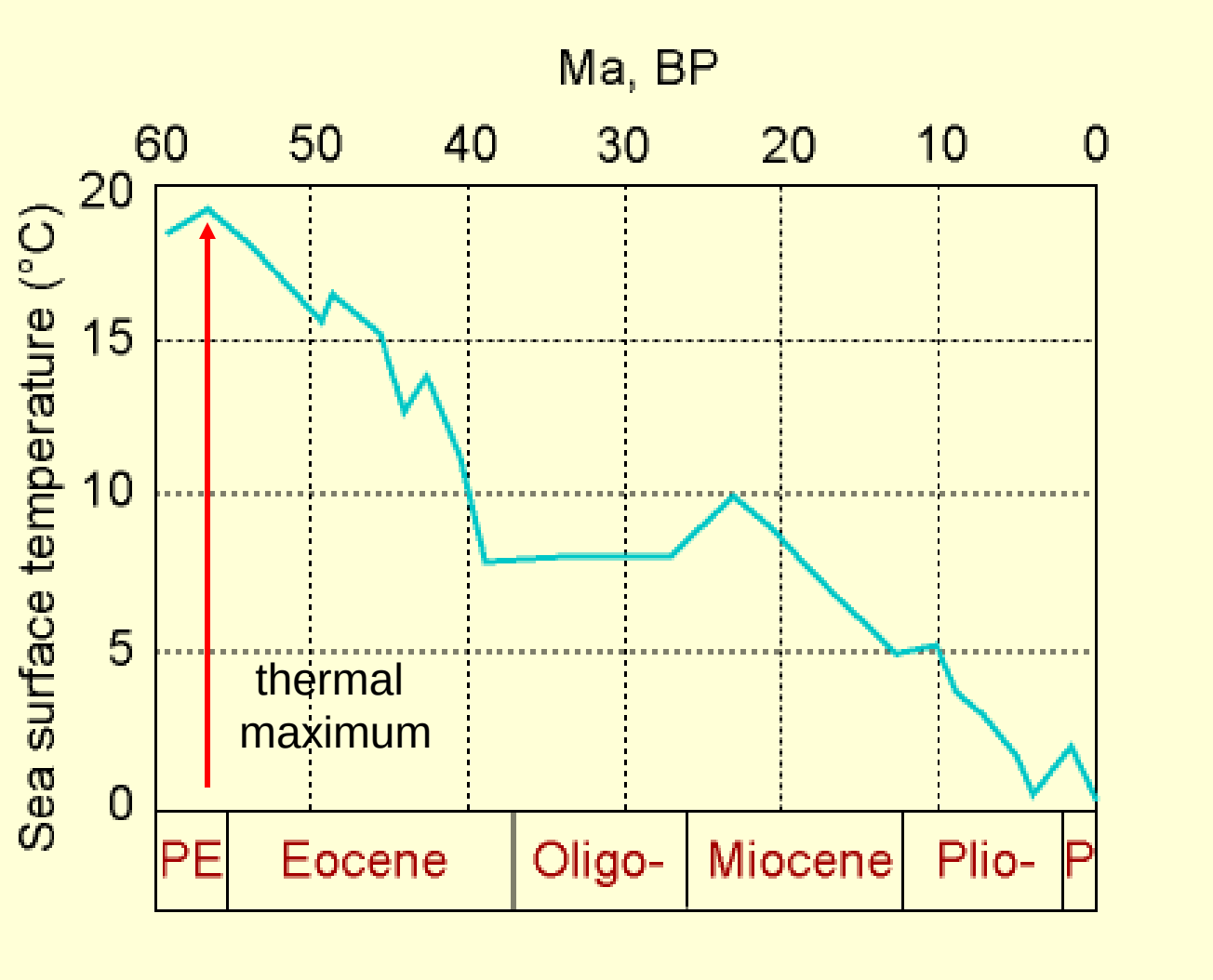


# 65Ma of climate change in the Cenozoic era




Mean annual temperatures in NW Europe and NW North America (reconstructed from pollen data) shown in red

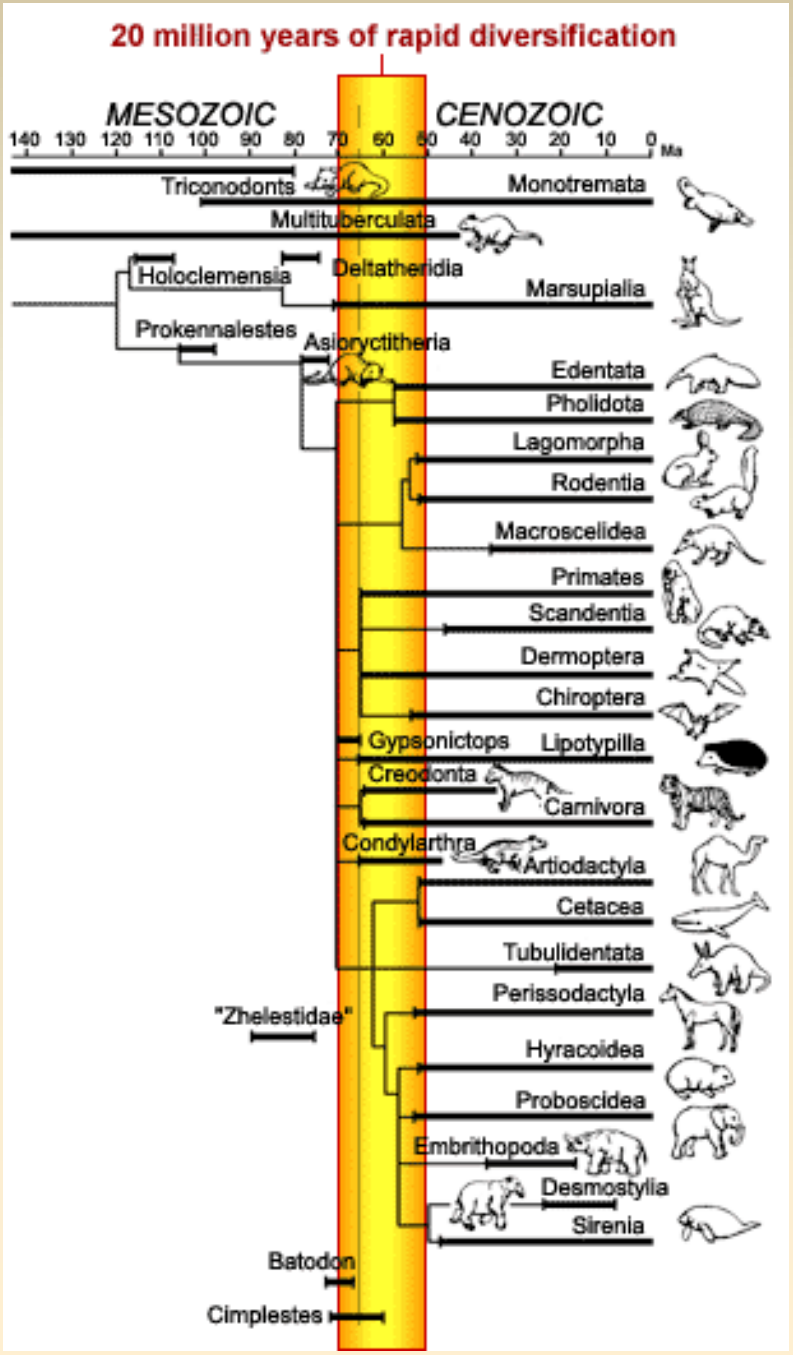
# Cenozoic climate change: the record from sub-Antarctic waters

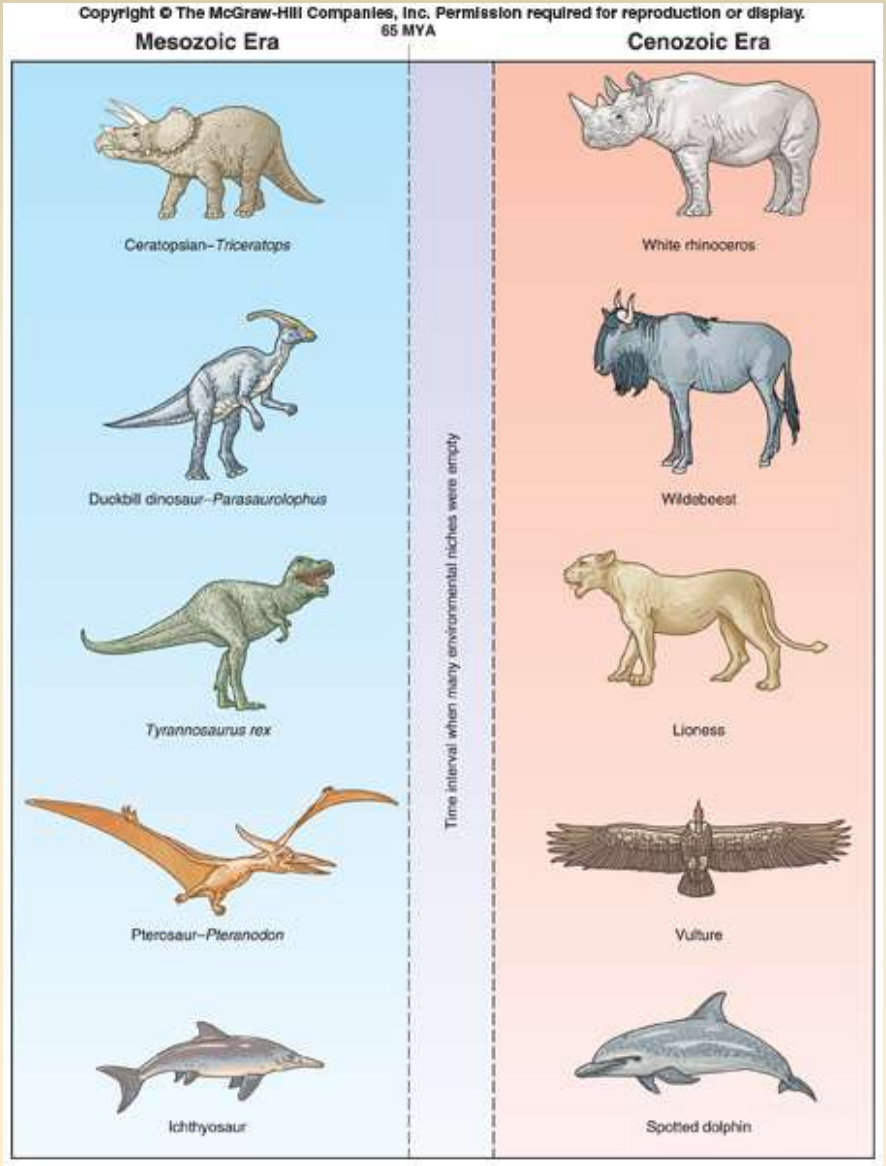


# Mammal Diversification

- With the demise of dinosaurs and their relatives,
  - mammals quickly exploited the adaptive opportunities,
  - beginning a remarkable diversification
  - that continued throughout the Cenozoic Era
- The Age of Mammals had begun

Mammals took over the role of the Dinosaurs.



# Evolution of Mammals

- Mammals evolved during the Late Triassic,
  - and some Mesozoic mammals retained characteristics of their ancestors,
    - the cynodonts.
- Cenozoic time,
  - Earth's flora and fauna became increasingly familiar
  - mammals clearly differentiated from their ancestors
  - grazing mammals appeared
  - first hominids

# Cenozoic Life

- Advent of Mammals
  - Archaic Mammals> Paleogene
  - Modern Mammals> Neogene
- Diversity of Mammals
  - Marsupial > earliest > pouched
  - Placental > Advanced > direct birth
- Carnivores
- Ungulates > Hoofed Herbivores, Most abundant and diversified (primitive)
  - Perissodactyles (odd-toed)> horse, rhino
  - Artiodactyles (even-toed, cloven hoofed)> cattle, pigs, sheep, goats, deer, antelope

- Birds evolved during the Jurassic,
  - families now common appeared during the Paleogene and Neogene,
  - reached their maximum diversity during the Pleistocene Epoch,
  - have declined slightly since then

The penguin ancestor *Copepteryx* lived well after the dinosaurs, during the Cenozoic Era

# Cenozoic Vegetation

- During the Cenozoic, Angiosperms, or flowering plants, continued their diversification as more and more familiar types of plants evolved.
- Gymnosperms also common.
- Many early Cenozoic plants would be quite familiar to us today, but their geographic distribution was very different.
- Grasses become widespread in Miocene

# Paleocene

65 –55 MY ago

# Early Paleocene Forest in Wyoming

In the early Paleocene, dense forests extended to higher latitudes. This scene is from the Early Paleocene of Wyoming. The vegetation included sequoia trees, with a dense undergrowth of shrubs such as tea and laurel, with the addition of ferns and horsetails.

# Mostly Small Creatures

- The Paleocene mammalian fauna
  - was also made up mostly of small creatures
- By Late Paleocene time, though,
  - some rather large mammals were around,
  - although giant terrestrial mammals did not appear until the Eocene

# Paleocene Tropical Forest in Colorado

# Paleocene Flora

- Paleocene rocks
  - in North America's western interior have fossil ferns and palms, both indicating a warm subtropical climate
- In a recently discovered Paleocene flora
  - in Colorado with about 100 species of trees, nearly 70 percent of the leaves had smooth margins and many had drip tips
- This range of diversity is much like that found in today's rain forests

***Coryphodon*** - a pantodont, a member of the world's first group of large browsing mammals.

Coryphodon reached about a metre in height and a weight of half a tonne, and also had the dubious distinction of having the smallest brain/body weight ratio of any mammal living or extinct.

# Giant flightless birds of prey

Giant flightless birds of prey like *Diatryma* appear suddenly during the late Paleocene and continue through to the Middle Eocene. Standing 2 meters or more in height and weighing in at around 200 kg, these large-beaked birds were the biggest and fiercest animals on land for some five or ten million years.

# Eocene

55 –33  MY ago

# Eocene - Subtropical Conditions

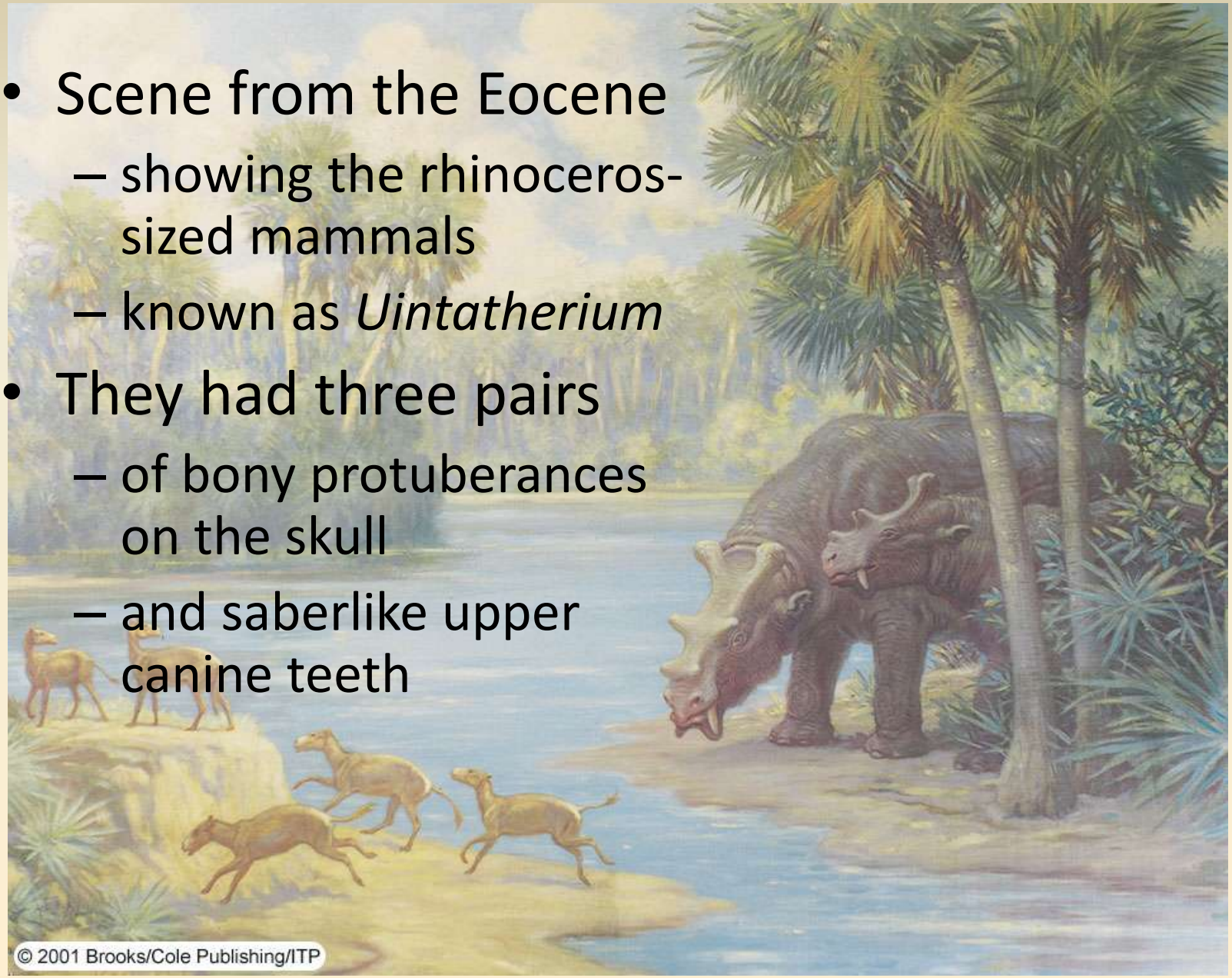
- Subtropical conditions persisted
  - into the Eocene in North America,
  - probably the warmest of all the Cenozoic epochs
  - probably due to a large methane release from the ocean floor
- Fossil plants in Oregon
  - include ferns, figs, and laurels,
  - all of which today live only in the humid parts of Mexico and Central America

# Eocene Landscape

# Giant Mammals Evolved

- With the evolution of a now extinct order
  - known as the Dinocerata,
  - better known as uintatheres,
  - and the strange creature known as *Arsinoitherium,*
  - giant mammals of one kind or another
  - have been present ever since

# Uintatheres



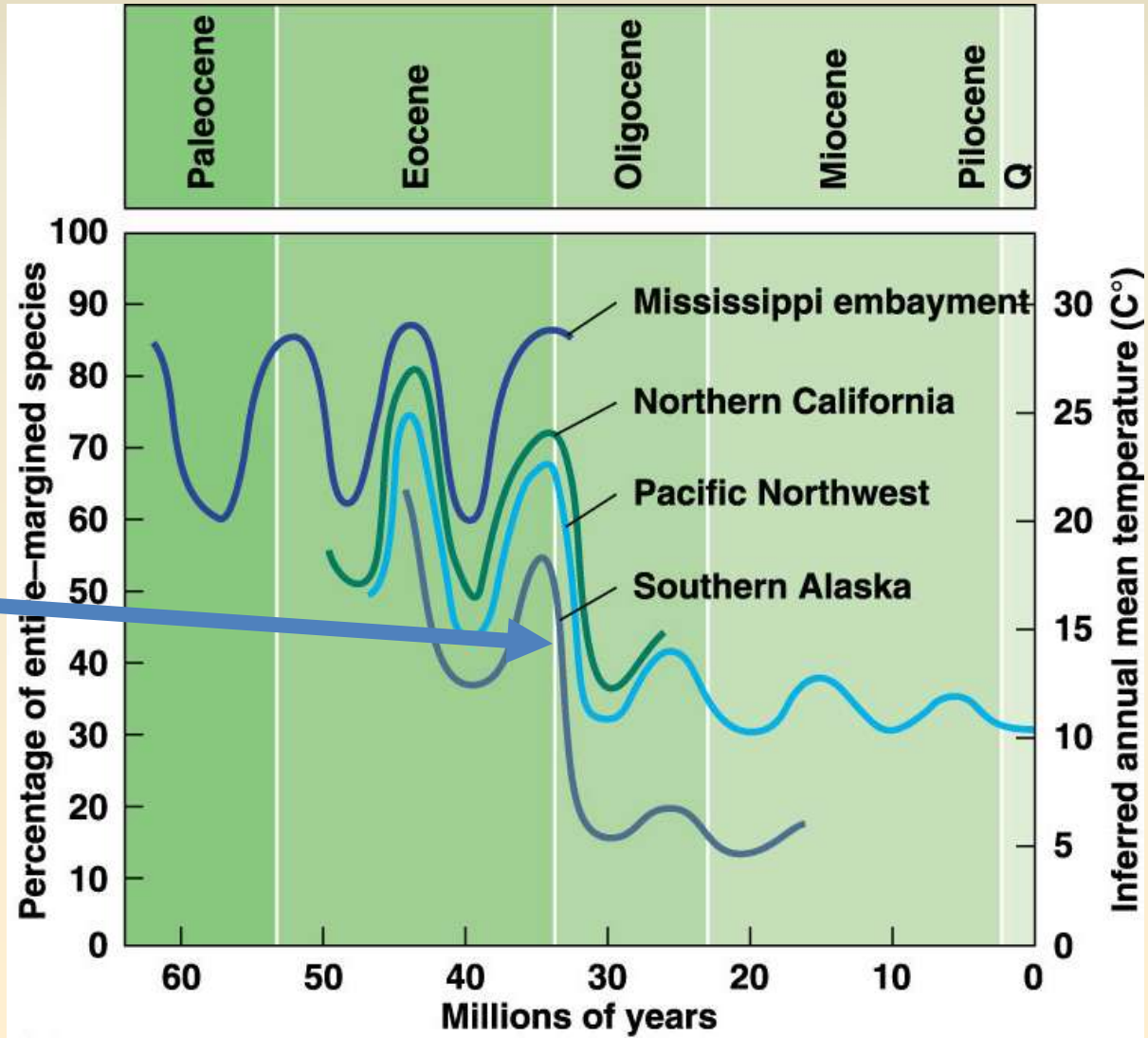
- Scene from the Eocene
  - showing the rhinoceros-sized mammals
  - known as *Uintatherium*
- They had three pairs
  - of bony protuberances on the skull
  - and saberlike upper canine teeth

# Subtropical Eocene Forest in Wyoming

The forest is composed of deciduous hardwood trees, as well as palms and early cacti. In the higher mountains surrounding the lakes, the forest contains mixed conifers and deciduous hardwood trees. These lush surroundings supported a diverse fauna of mammals, both on the ground and in the trees, including early relatives of living rodents, lemurs, and horses

# Major Climatic Change

- A major climatic change took place at the end of the Eocene
  - when mean annual temperatures
  - dropped as much as 7 degrees C
  - in about 3 million years



# Climatic Change

- Since the Oligocene,
  - mean annual temperatures have varied somewhat worldwide,
  - but overall have not changed much in the middle latitudes
  - except during the Pleistocene

# Archaic Paleocene Mammals Died Out

- Warm, humid climates persisted
  - throughout the Paleocene and Eocene,
  - but by Oligocene time
  - drier and cooler conditions prevailed
- Most of the archaic Paleocene mammals
  - as well as several groups
  - that originated during the Eocene
  - had died out by this time
- The uintatheres and
  - large, rhinoceros-like titanotheres
  - went extinct

# Oligocene

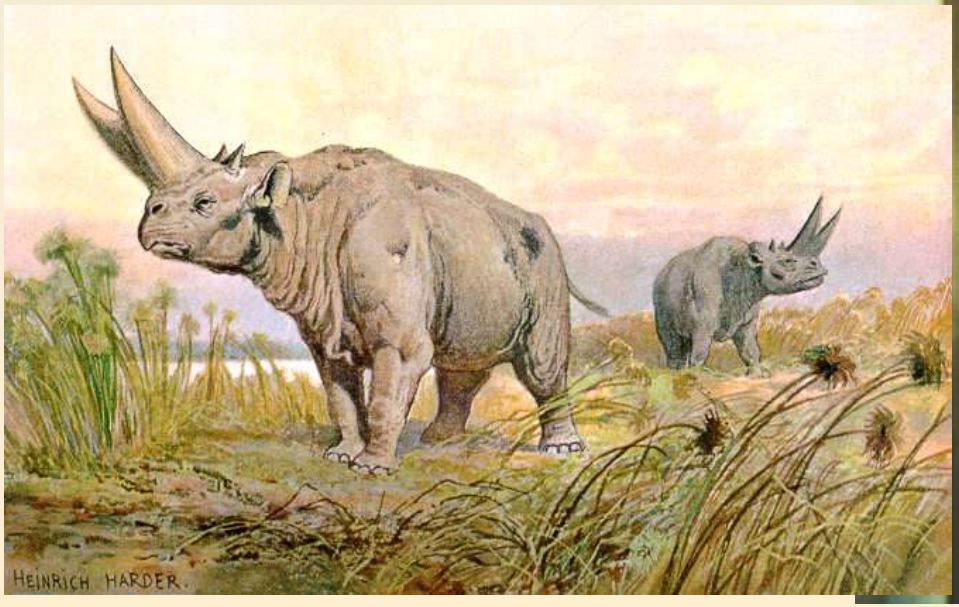
33 –23 MY ago

# Oligocene

- By Oligocene time,
  - most of the existing mammalian orders
  - were present,
  - but they continued to diversify
  - as more and more familiar genera evolved
- If we were to encounter some of these animals
  - we might think them a bit odd,
  - but we would have little difficulty recognizing
  - rhinoceroses, although some were hornless,
  - elephants, horses, rodents, and many others

# *Arsinoitherium*

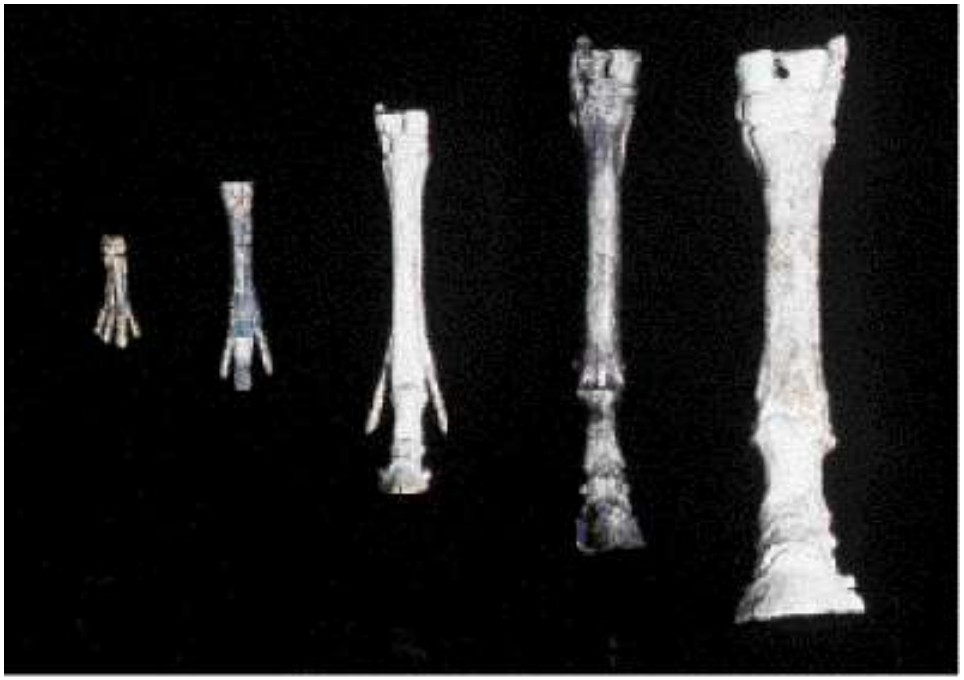
- Skull of *Arsinoitherium*
  - a rhinoceros to elephant-sized
  - Early Oligocene animal
  - with hollow horns more than 0.5 m long



# Oligocene – Grasslands and Horses


*Mesohippus bairdi*, a browsing, short-necked, three-toed Oligocene horse (Perissodactyla, Equidae). It fed on leaves (not grass) stood about 55 cm tall.

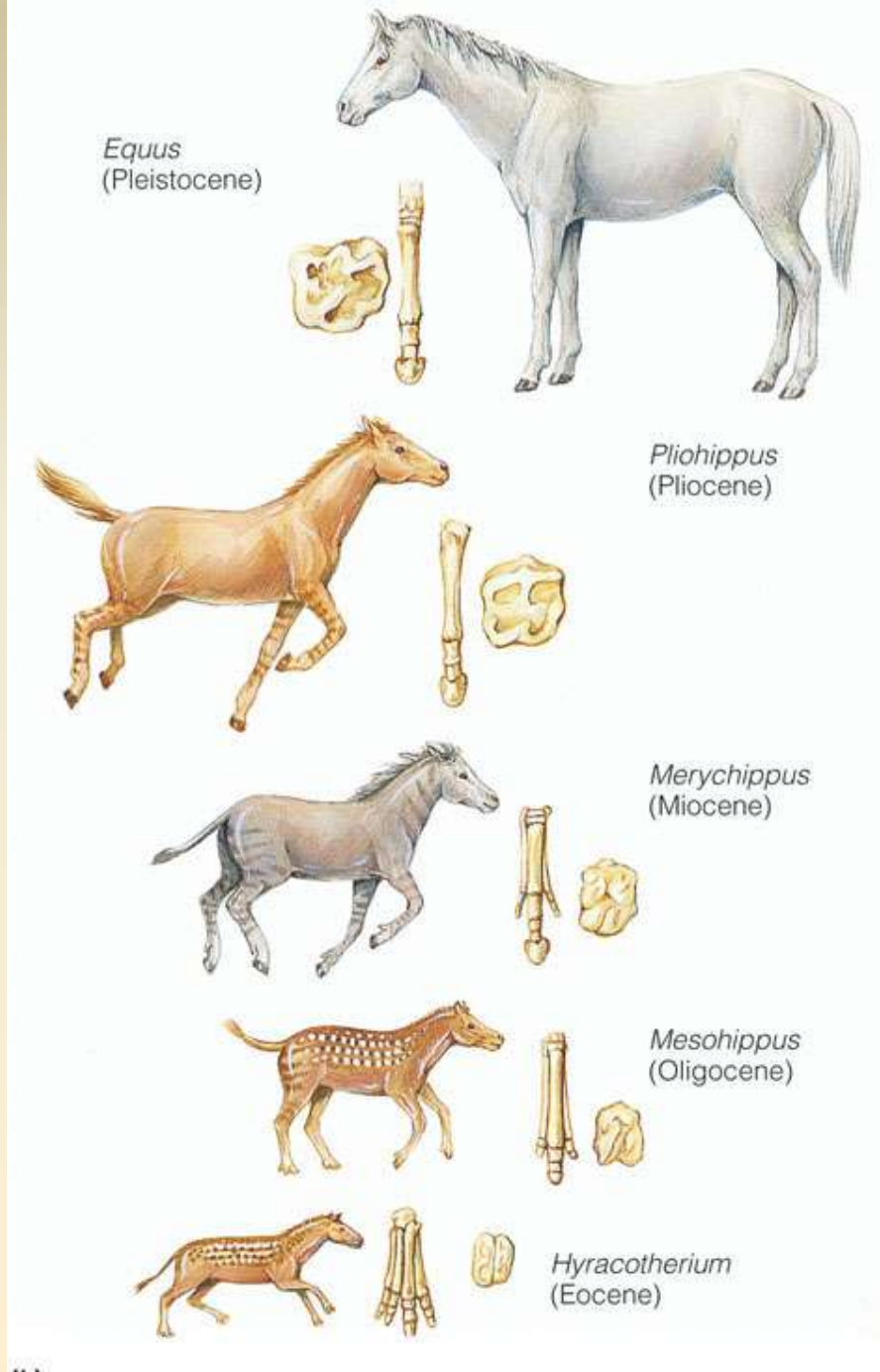
The horse family - Equidae - was an especial success story during the Neogene. Horses and other grazing mammals evolved high-crowned teeth to cope with a diet of abrasive grass.



*Hyracotherium* ancestral horse, ancestor of all perissodactyls, small 4, 3 toed animal to *Equus*, large complex enamel molars, one toe

# Horse Evolution

- Some evolutionary trends in horses
  - include an increase in size
  - lengthening of the limbs
  - reduction in the number of toes
  - and development of high-crowned teeth
  - with complex chewing surfaces




(b)

# Paraceratheriums – giant mammals in Asia

Paraceratheriums were perissodactyls. The giant creatures were most closely related to the living rhinoceroses (although they shared ancestors with tapirs and horses as well). Paraceratherium's immense size allowed it to eat the branches and leaves of large trees.

# Miocene

23 – 5  MY ago

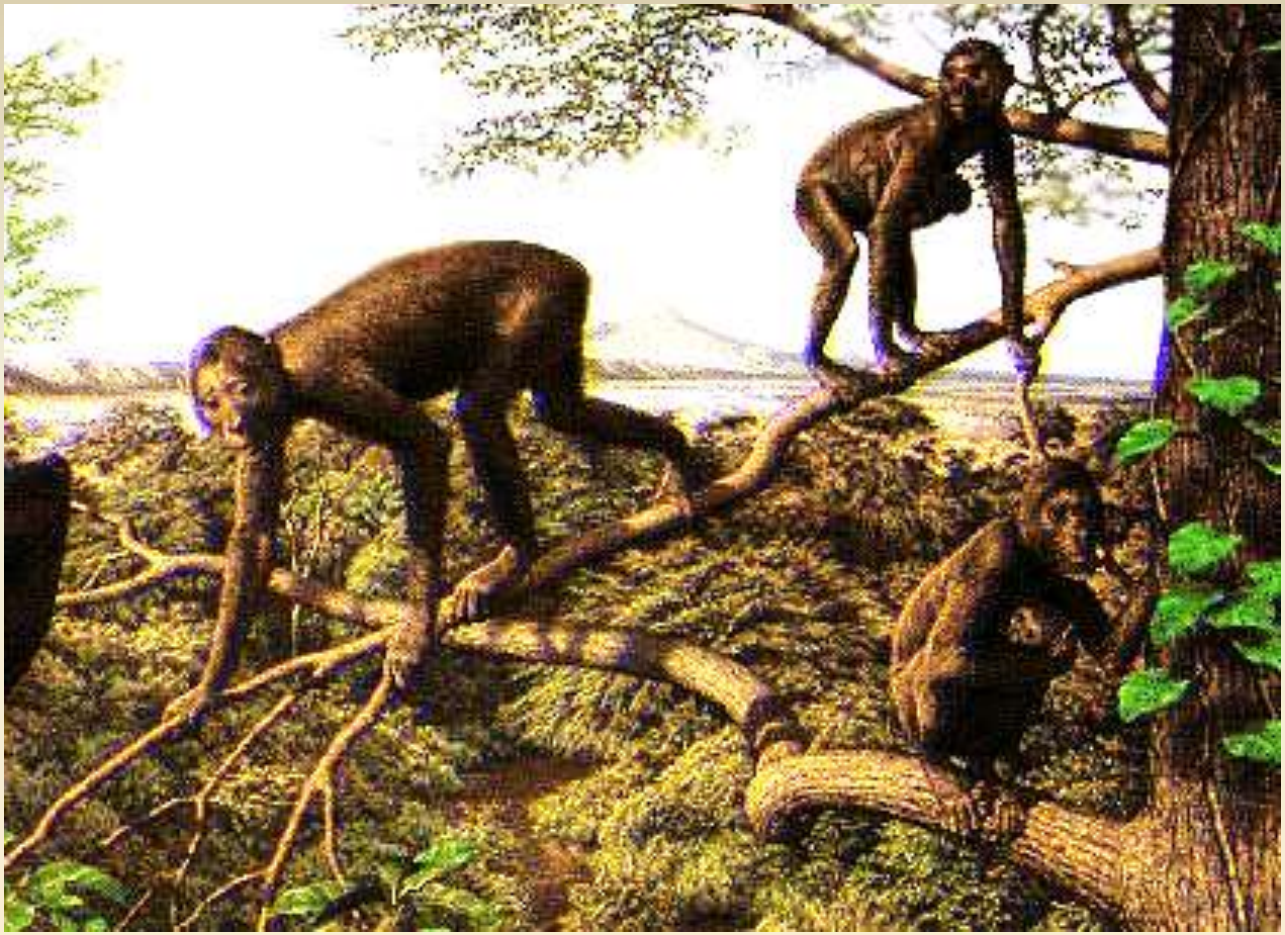
# Miocene North Dakota – 10 MYA

Late spring in the Northern Great Plains about 10 million years ago, in what is now southern South Dakota. The Black Hills appear in the background, and a shallow stream with braided sandbars winds through the foreground. The water in the stream is deep enough to support a group of beavers. Grasses, shrubs, and trees growing along the streamside provide ample cover for a wolf-size carnivore, distantly related to modern dogs, to stalk the beavers and horses drinking from the stream

# Primate Evolution

- By Oligocene time
  - primitive New World and Old World monkeys
  - had developed
  - in South America and Africa, respectively
- The Hominoids,
  - the group that includes apes and humans,
  - evolved during the Miocene

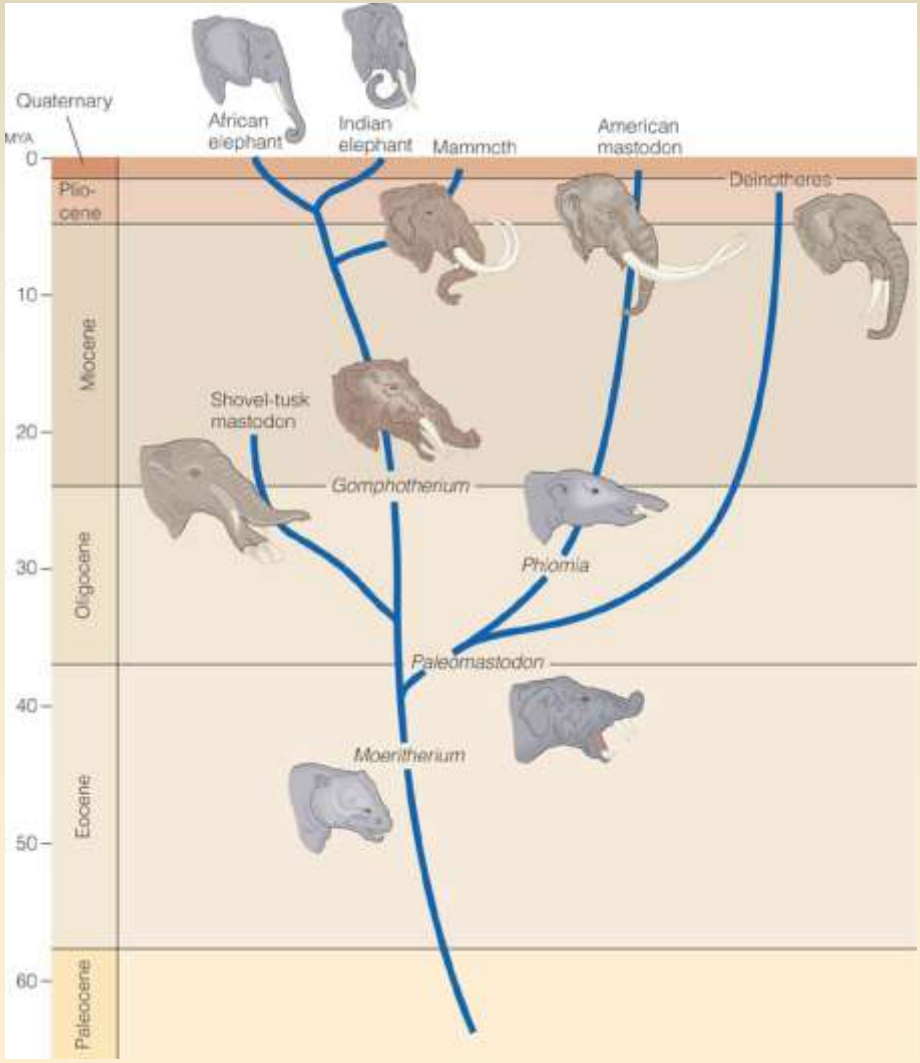
# Miocene Ape: Proconsul



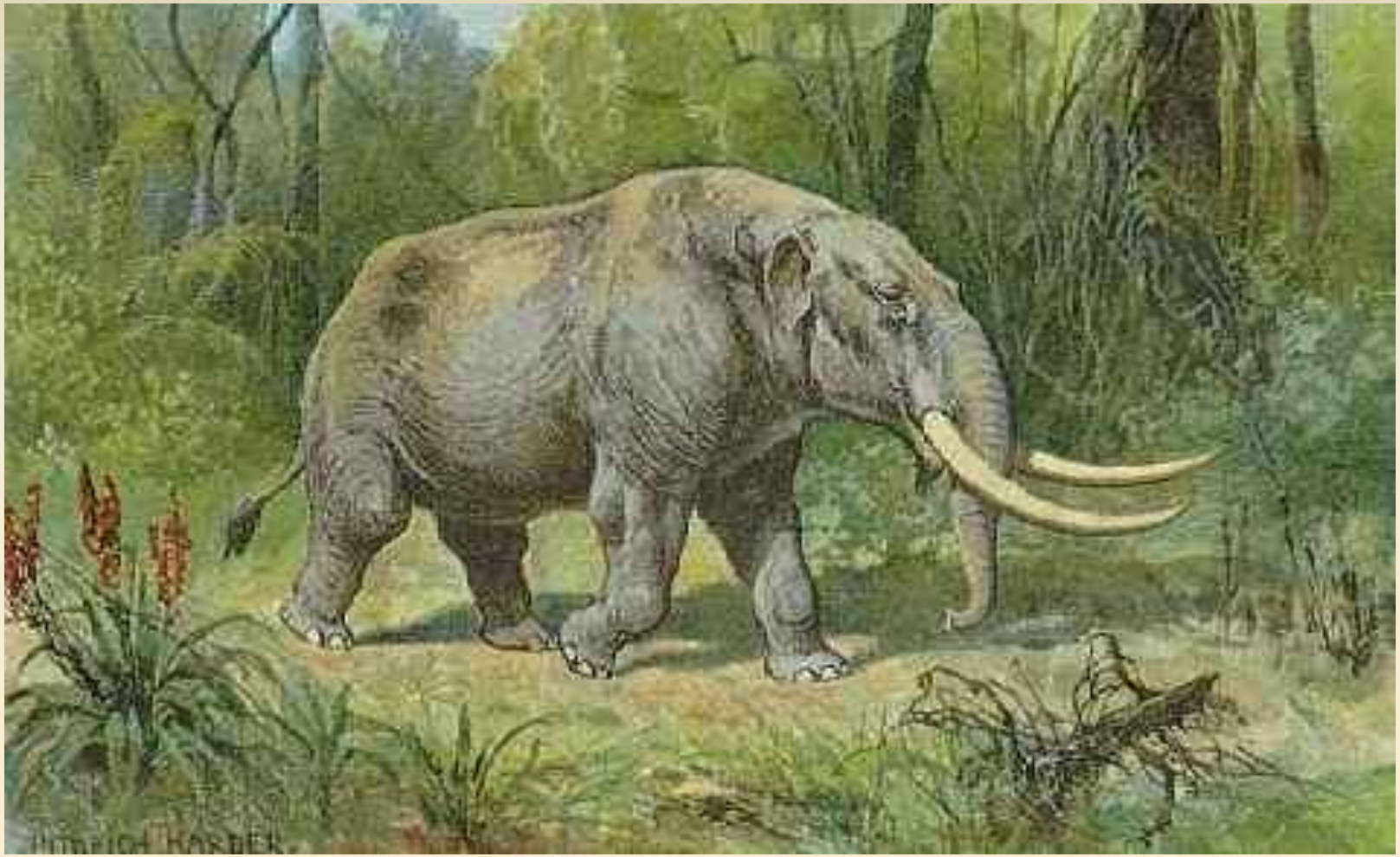
*Proconsul africanus* is one of the very first primates that can be classified as an ape. It lived 25-15 million years ago in the forests of Eastern Africa, but had cousins spread all over the old world. Since it is such a basal hominoid, it shares certain features with both monkeys (catarrhines) and apes.

# Giant Land-Dwelling Mammals
# Elephants

- During much of the Cenozoic,
  - proboscideans of one kind or another
  - were widespread on the northern continents,
  - but now only two species exist,
  - one in southeast Asia and one in Africa



The Mastodons lived on every continent except Australia.

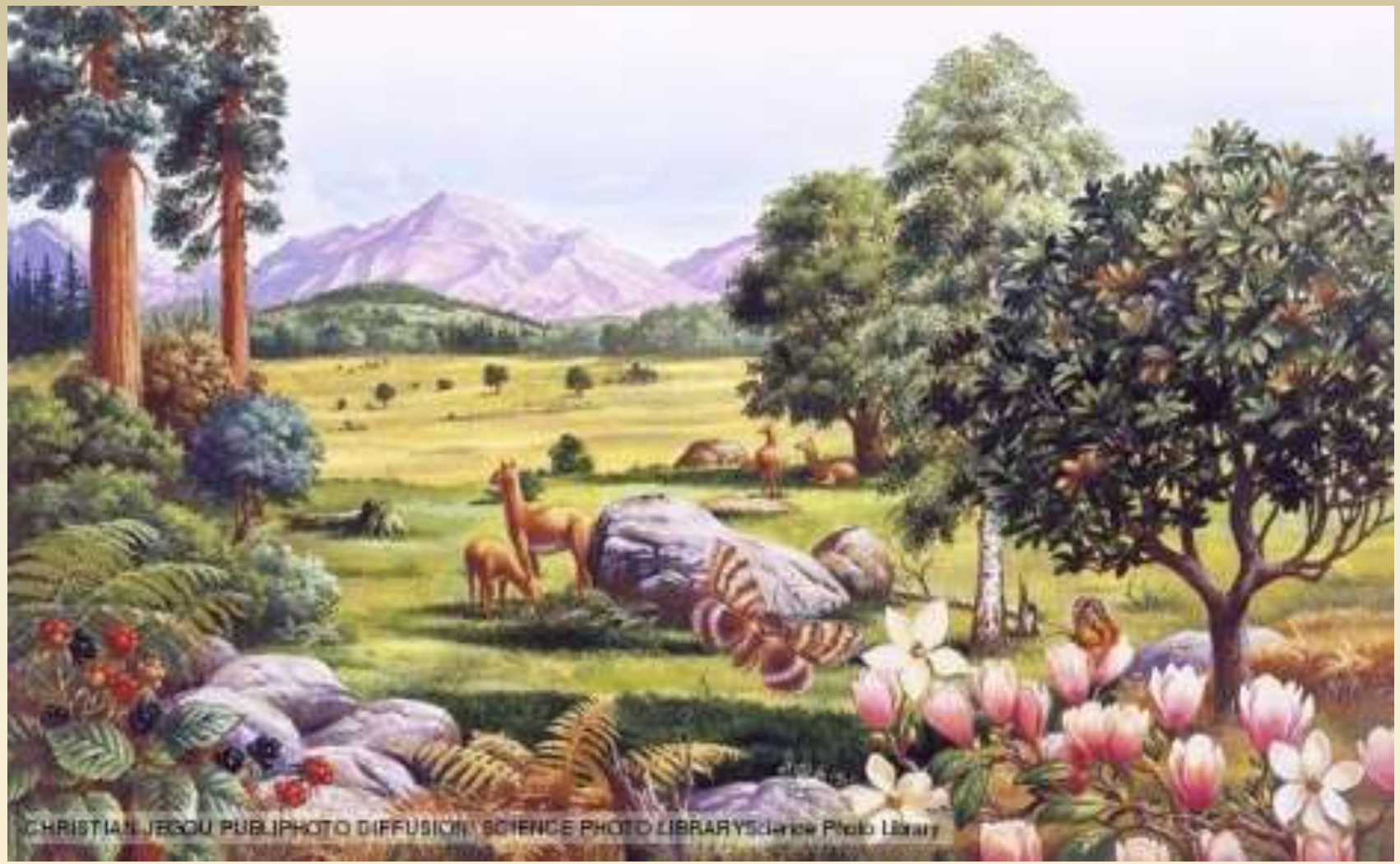


# Pliocene

5.3 - 2.6 MYA

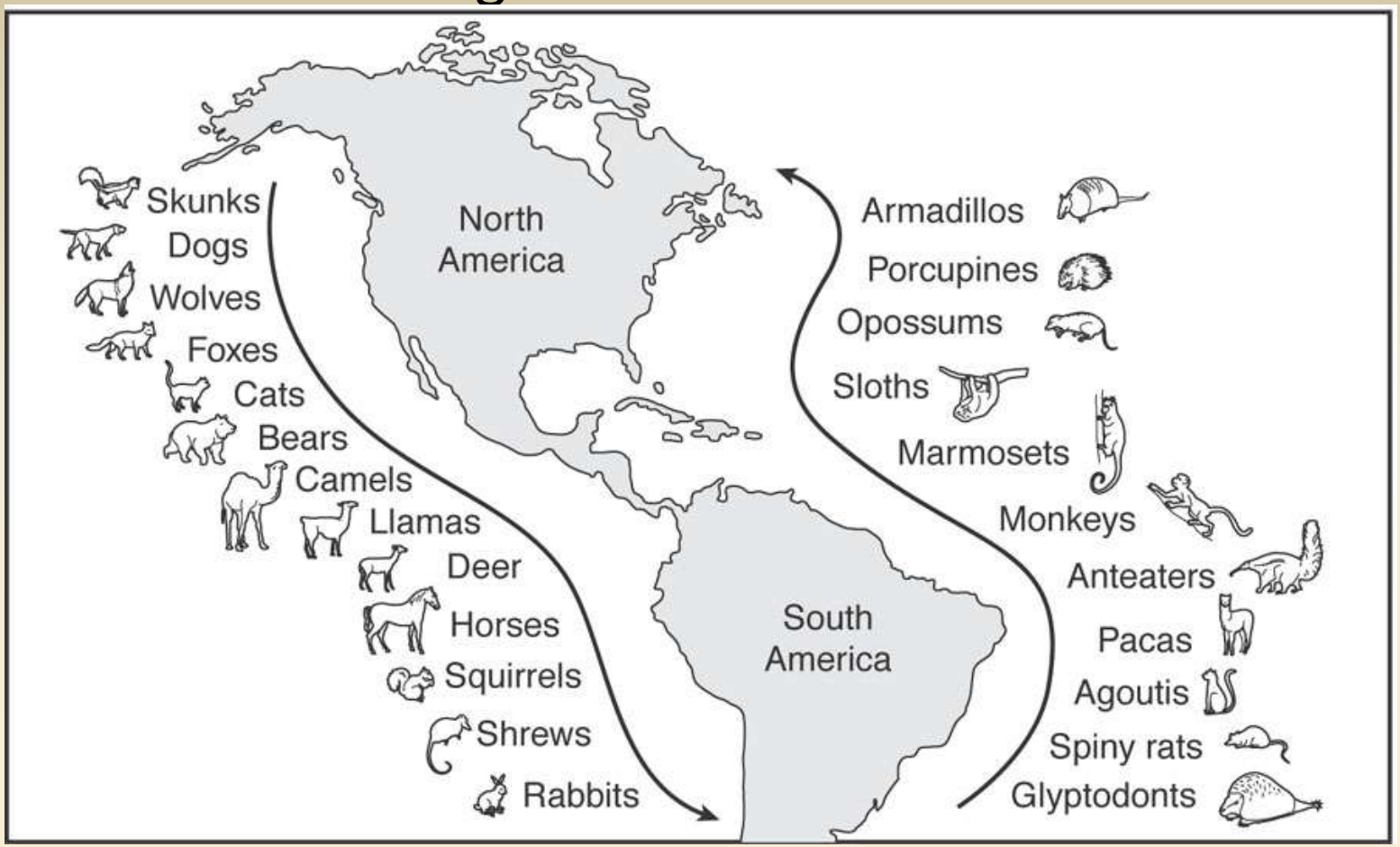
# Pliocene

- Climatic cooling continues, with subtropical regions retreating equatorially, the beginning of the large ice caps, especially in Antarctica, and the northern hemisphere  lands and ocean cooling likewise.
- The fauna of the Pliocene does not differ much from that of the Miocene
- Climax of the Age of Mammals, with appearance of all of the presently existing orders and families, and many of the existing genera of mammals.




The Pliocene world looked very similar to Earth today as North and South America had been drifting ever closer and the gap between them was sealed in this epoch. As the world cooled in the late Pliocene, ice at the North Pole became permanent and grassland and tundra thrived. The human lineage split away from the chimpanzees' early on in the epoch.

# The Great Exchange — North and South America

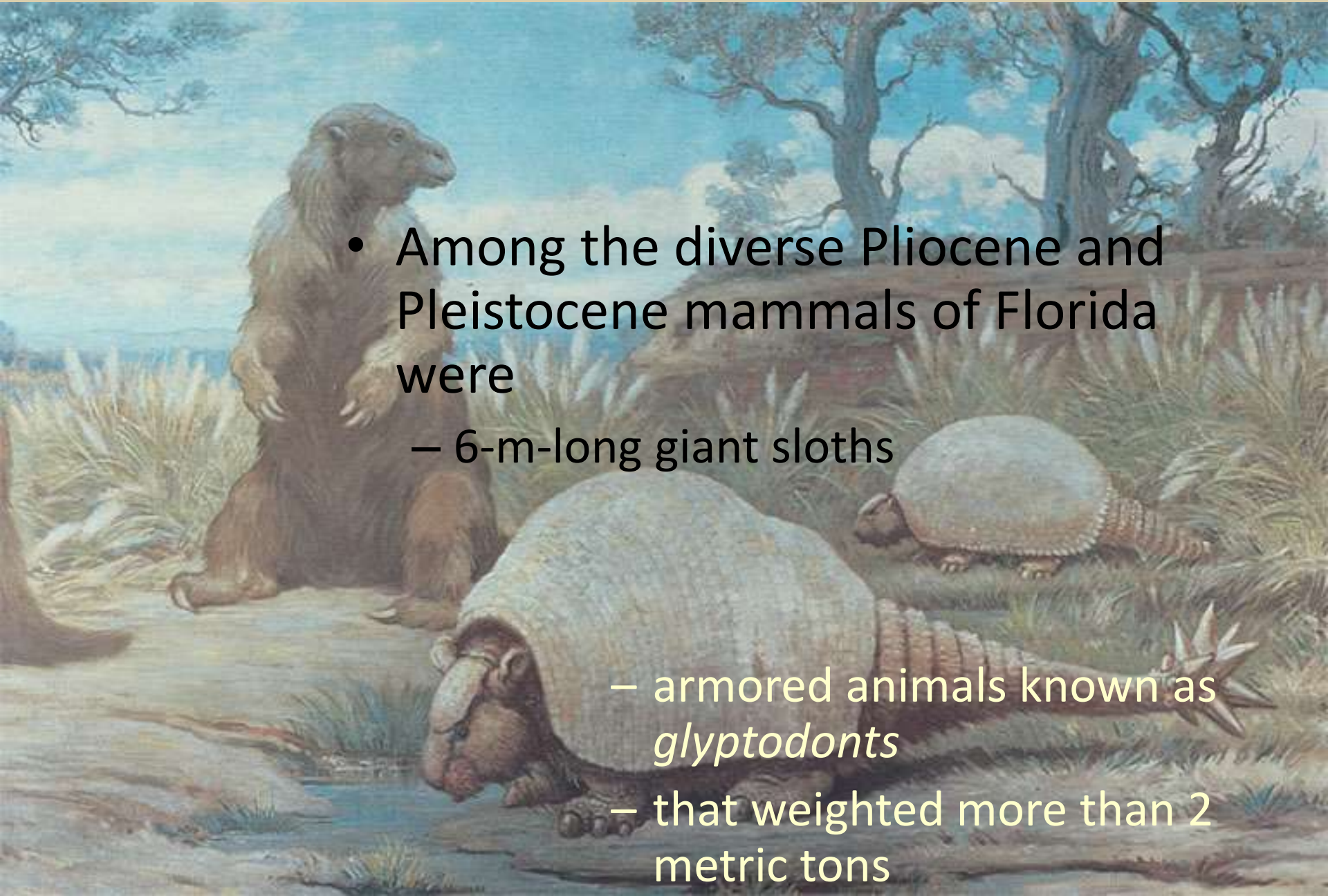



- Separate faunas and floras evolved on these continents when they were separate during the Cenozoic. About 2 to 3 million years ago, the Isthmus of Panama formed, providing a land bridge between the continents that became a route of migration and exchange between the continents. Among the placental mammals, many arising in North America dispersed south, and many originating in South America dispersed north.

Opossum

Armadillo

# Pliocene and Pleistocene



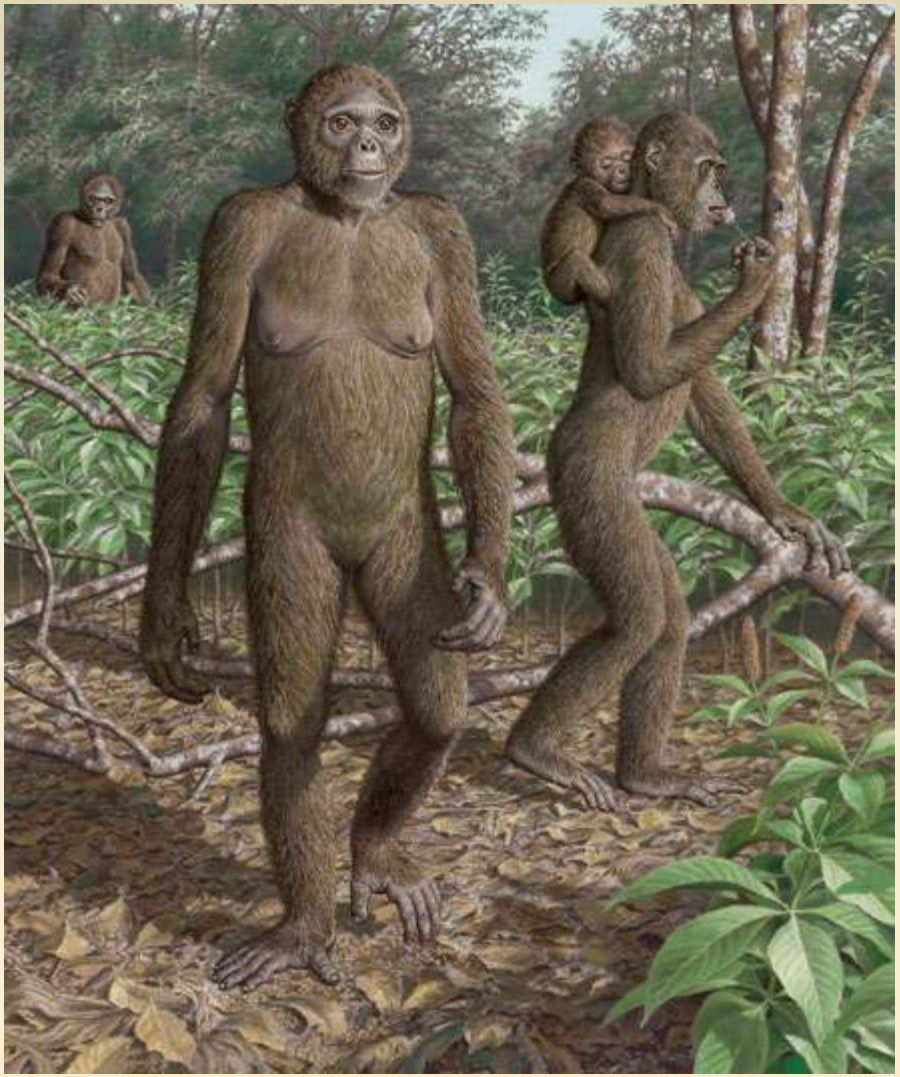
- Among the diverse Pliocene and Pleistocene mammals of Florida were
  - 6-m-long giant sloths
  - armored animals known as *glyptodonts*
  - that weighted more than 2 metric tons

# Giant Ground Sloths

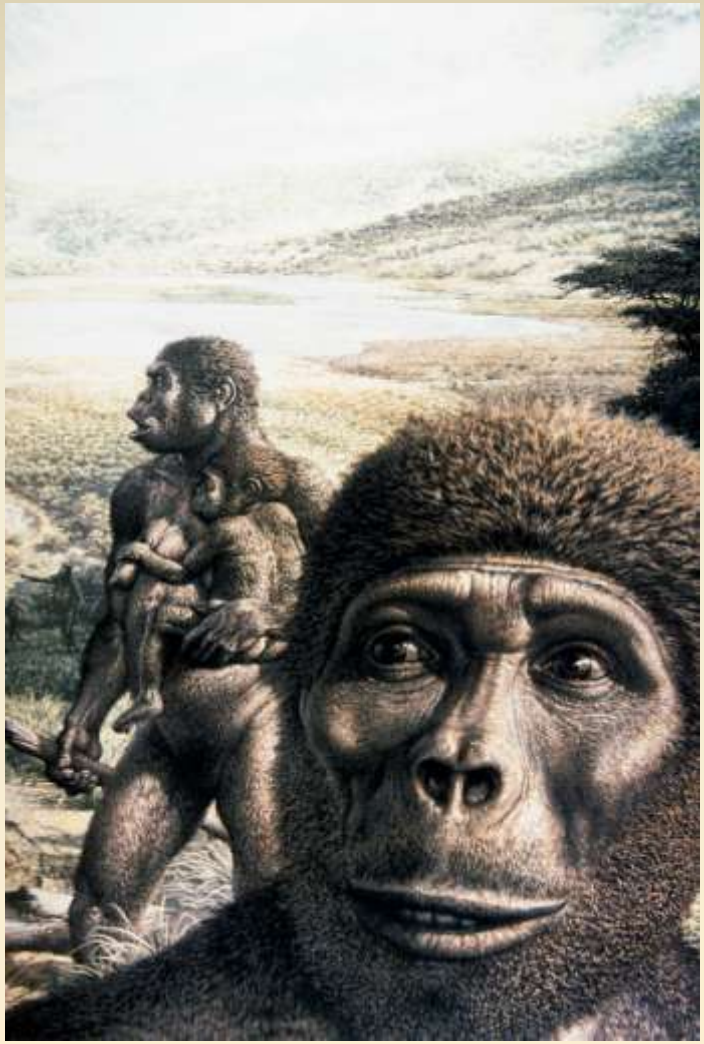

Megatheriidae

# Ardipithecus ramidus – 4.4 MYA


“It's not a chimp. It's not a human. It shows us what we used to be”
Tim White



# Hominids appeared in the Africa savannas, the Australopithecines.



3.9 mya: Appearance of *Australopithecus*, genus of hominids.

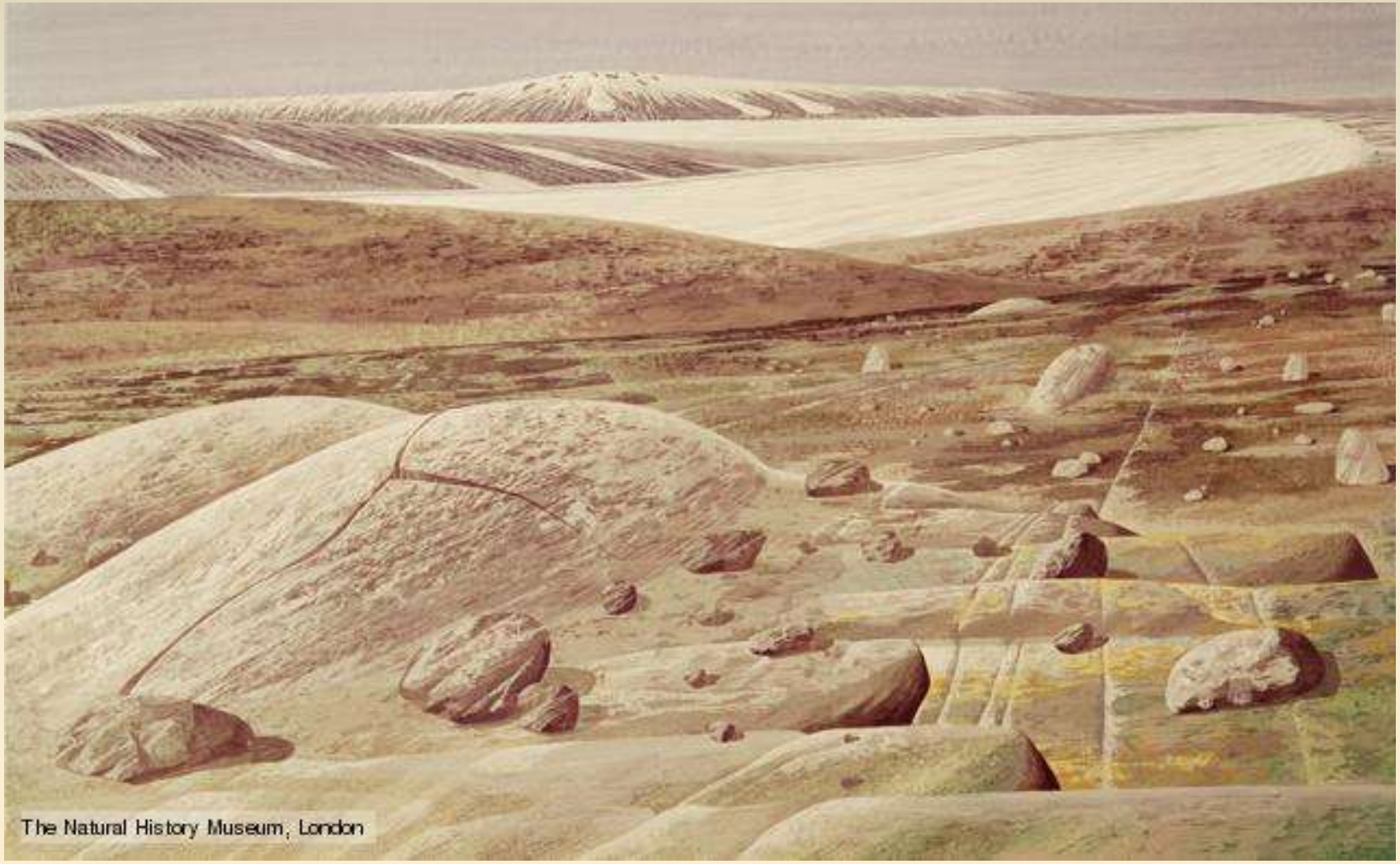
# Pleistocene

2.6-0.01 MYA

# The Pleistocene

- Pleistocene, the time period that spanned from 1.8 million to ~10,000 years ago.
- Pleistocene biotas were extremely close to modern ones — many genera and even species of Pleistocene conifers, mosses, flowering plants, insects, mollusks, birds, mammals, and others survive to this day.
- Pleistocene was also characterized by the presence of distinctive large land mammals and birds.
- Mammoths and their cousins the mastodons, longhorned bison, sabre-toothed cats, giant ground sloths, and many other large mammals characterized Pleistocene habitats in North America, Asia, and Europe.
- Native horses and camels galloped across the plains of North America. Great teratorn birds with 25-foot wingspans stalked prey.

**Pleistocene** - glaciers came and went, resulting in a series of ice ages punctuated by warmer periods. There were at least 20 cycles of this advance and retreat.

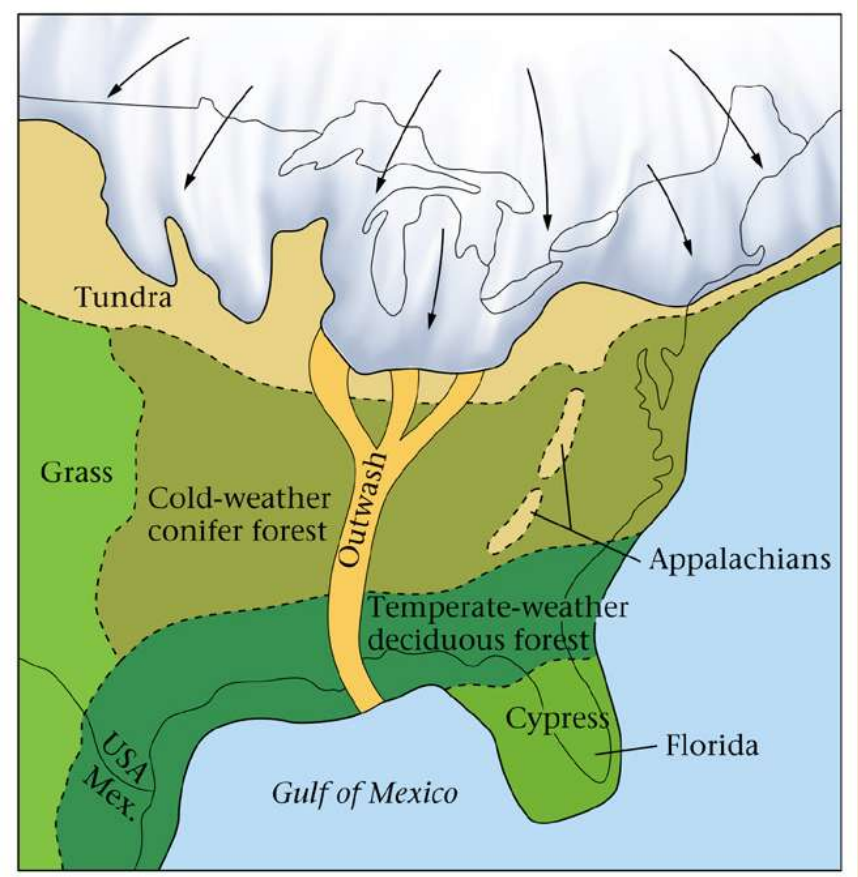


# Advance of the Ice Sheets

- The Late Pliocene and Pleistocene had strong, rapid, **climatic fluctuations**.
- Ice ages are characterized by **glacial expansions** separated by **warmer interglacial intervals**.
- Before the mid-1970's, the Pleistocene was divided into four glacial stages with intervening warmer interglacial stages.
- More recent investigations have shown that there may have been **as many as 30 glacial advances over the past 3 million years (roughly every 100,000 years.)**

# Pleistocene Glaciation of the Northern Hemisphere


Maximum Extent of glaciation in the Northern Hemisphere




**Climate Belts**

# Sea Level Change during the Past 20,000 Years

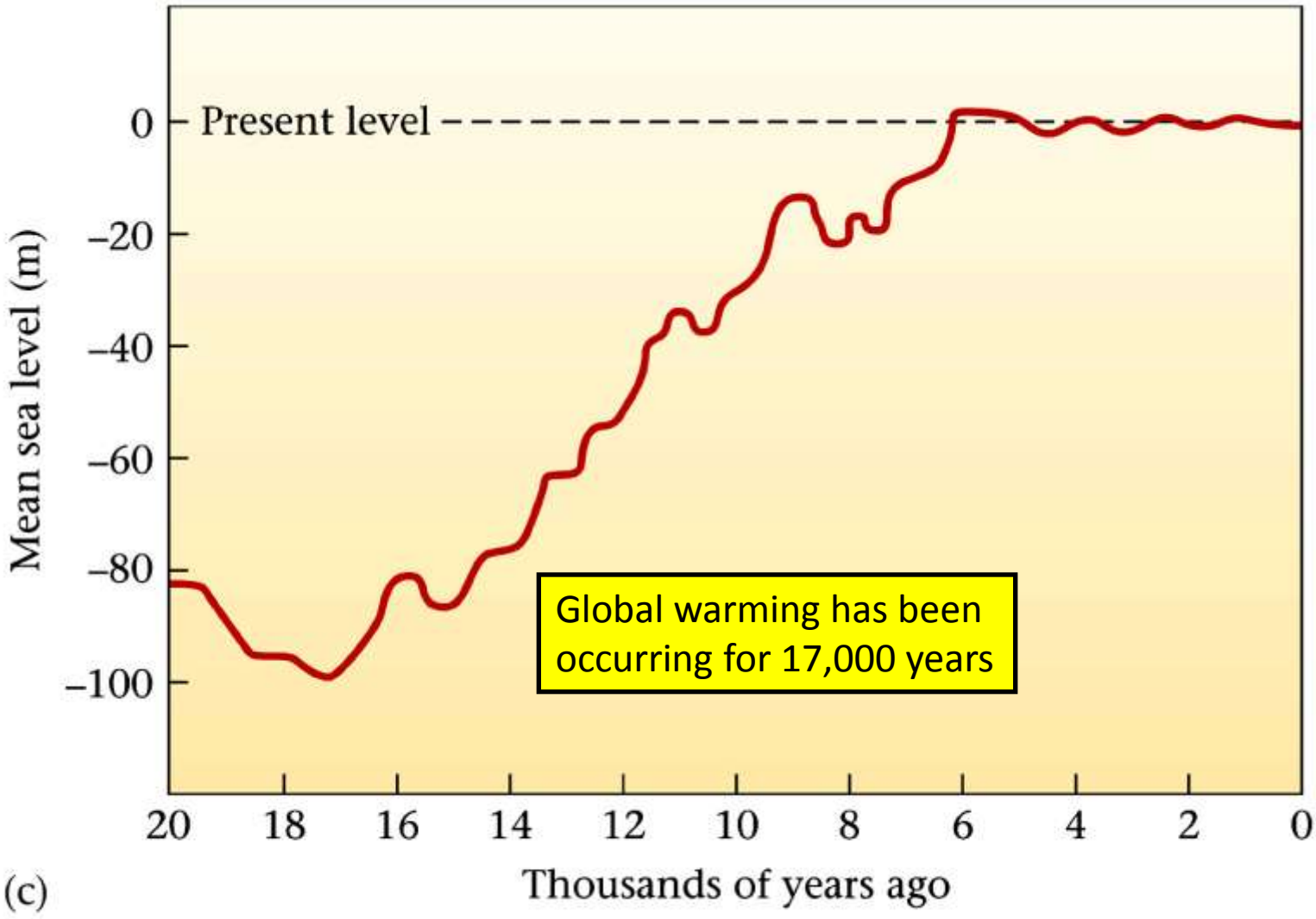
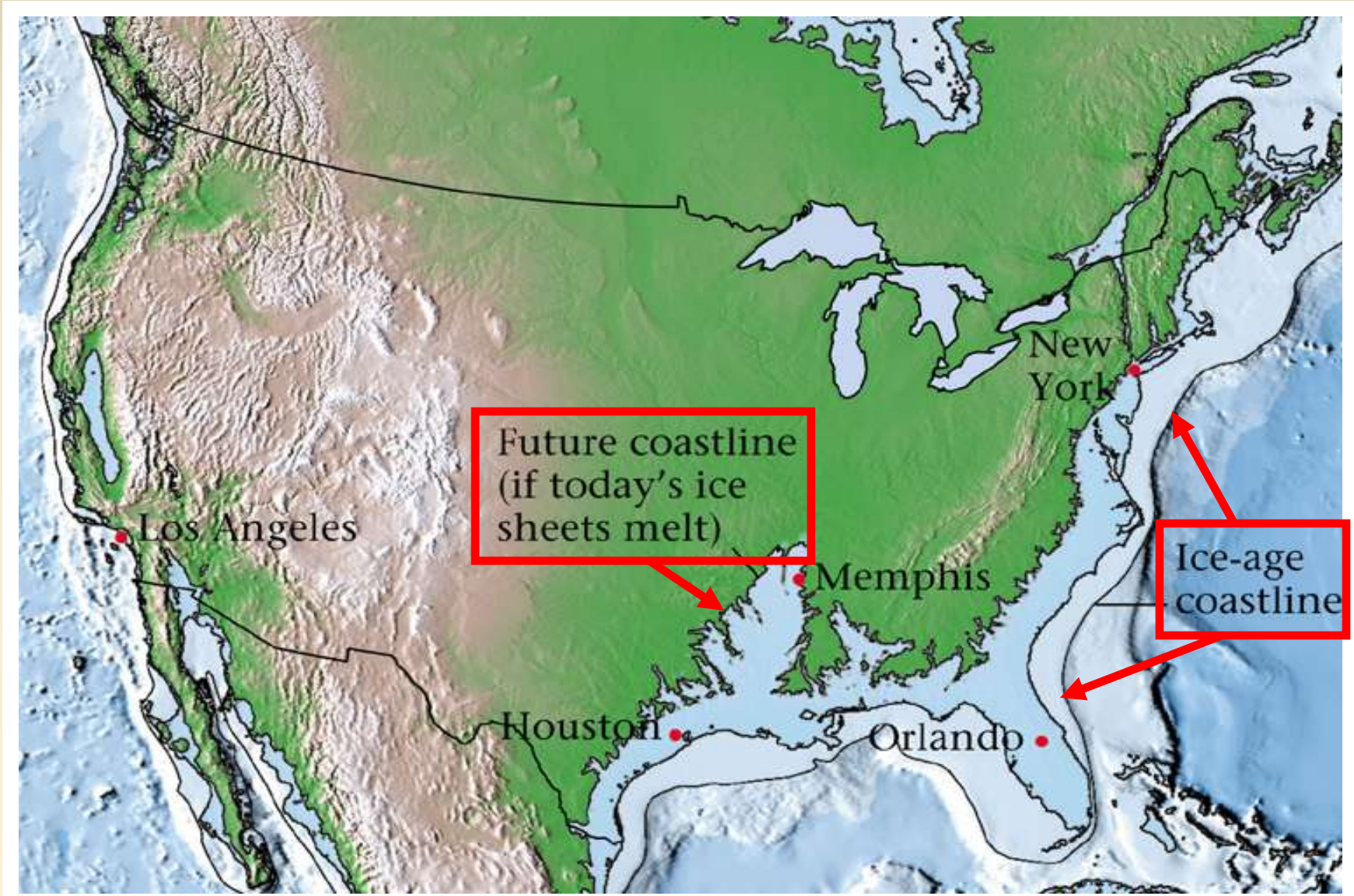



FIGURE 22.34

*Earth: Portrait of a Planet*, 2nd Edition

# Positions of the coastline of North America during the Ice Age and if the ice sheets melt



# What is thought to...

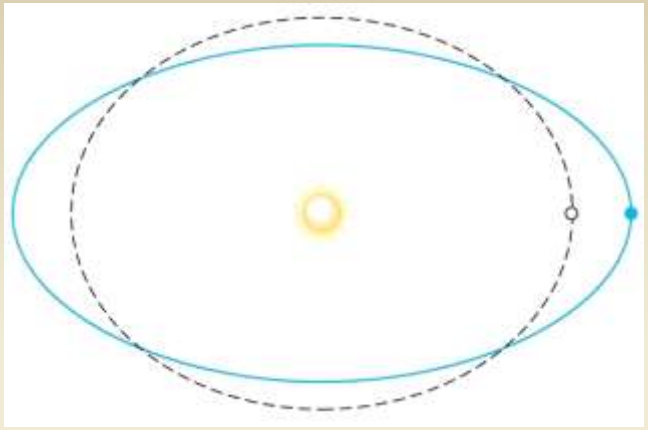
...have caused the Pleistocene Ice Age?

- Formation of Central America deflected the Gulf Stream and moist air northward, produce more snow
- Northward movement of North America and Eurasia provided more surface for snow accumulation

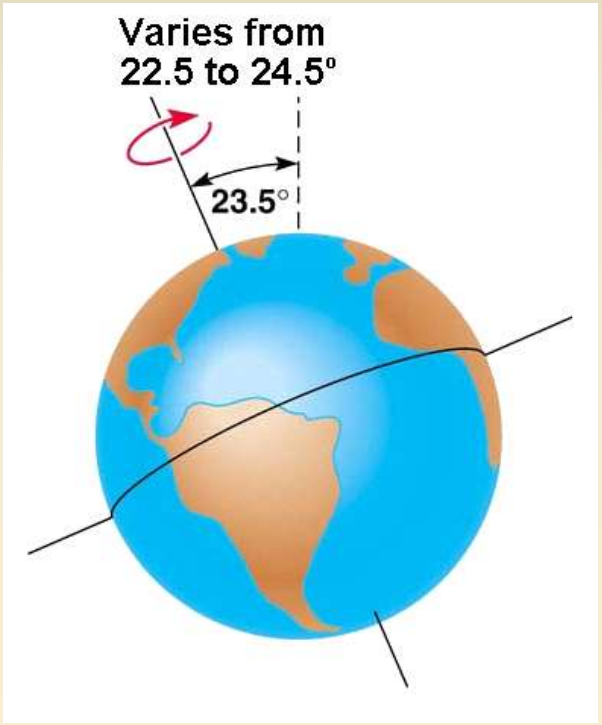
...also cause/contribute to occurrence of ice ages?

- Milankovitch cycles, natural periodic changes in
    - Earth's orbital eccentricity
    - Tilt of Earth's axis
    - Precession of Earth's axis, of the equinoxes
  - Cause periodic changes in the amount of sunlight at high latitudes
  - Lead to natural periods of global cooling and warming
- Excessive volcanism, etc.

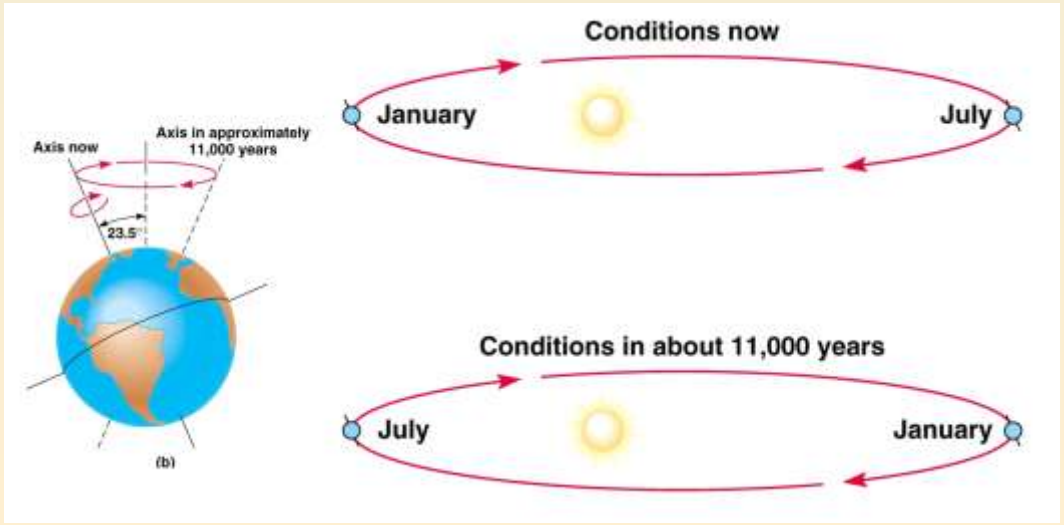
# Milankovitch Cycles



A change in Earth's orbital eccentricity occurs every 100,000 years




A 2 change in tilt of Earth's axis occurs every 41,000 years

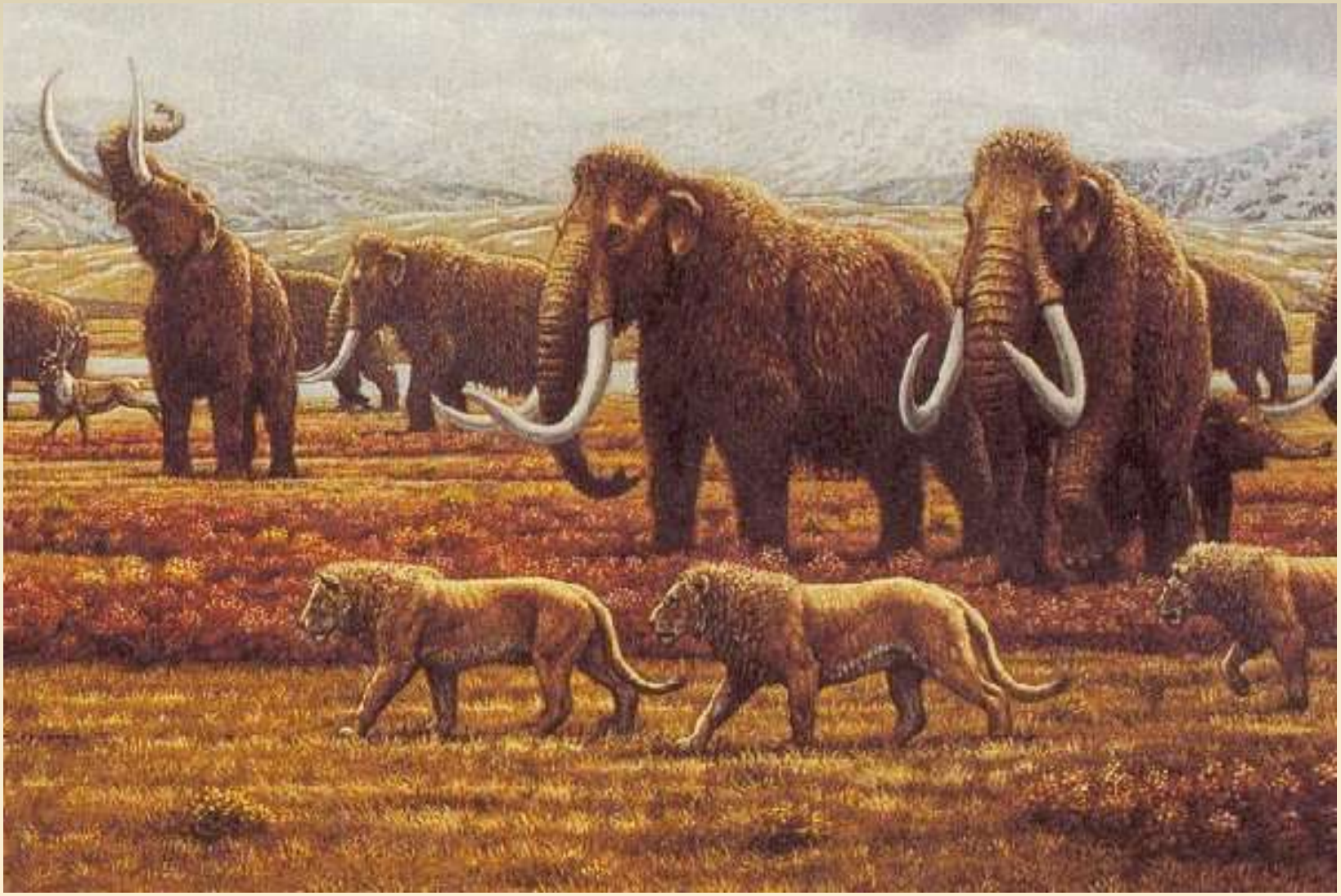



A precession of Earth's axis occurs every 23,000 years

# Mammals of the Ice Age

- The most remarkable aspect
  - of the Pleistocene mammalian fauna
  - is that so many very large species existed
- Mastodons, mammoths, giant bison,
  - huge ground sloths, immense camels,
  - and beavers 2 m tall
  - at the shoulder were present in North America
- South America had its share of giants, too,
  - especially sloths and glyptodonts

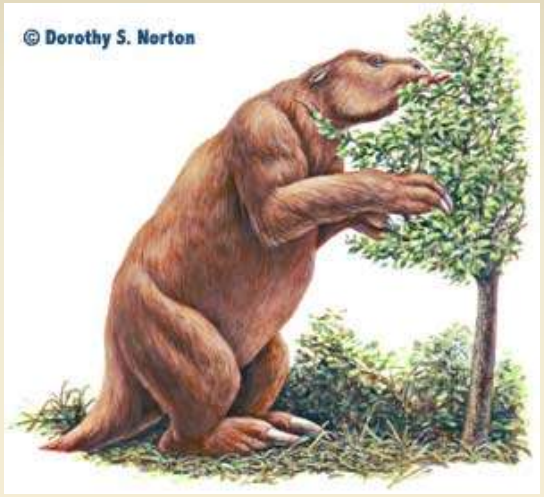
# Pleistocene Megafauna

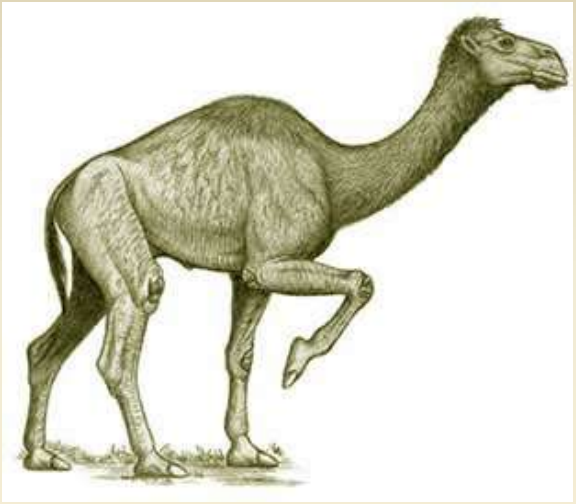


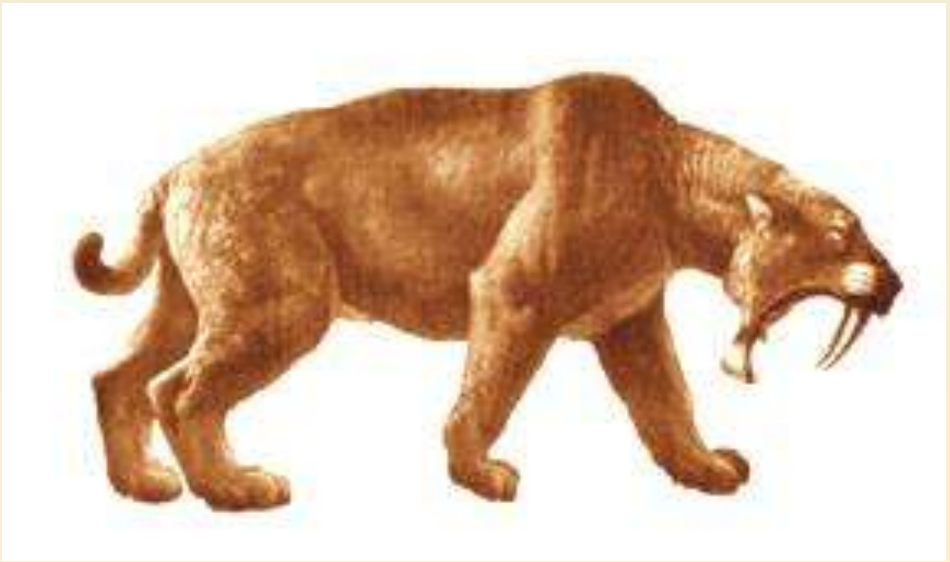
The ice age was at its most extreme - and the climate at its most severe - 18,000 years ago.


Spain – horses, wooly mammoth, lions, wooly rhinoceros

North America supported a rich “megafauna” until about 11,000 years ago.  Rivaled modern-day Africa





# Scabre-toothed Cat

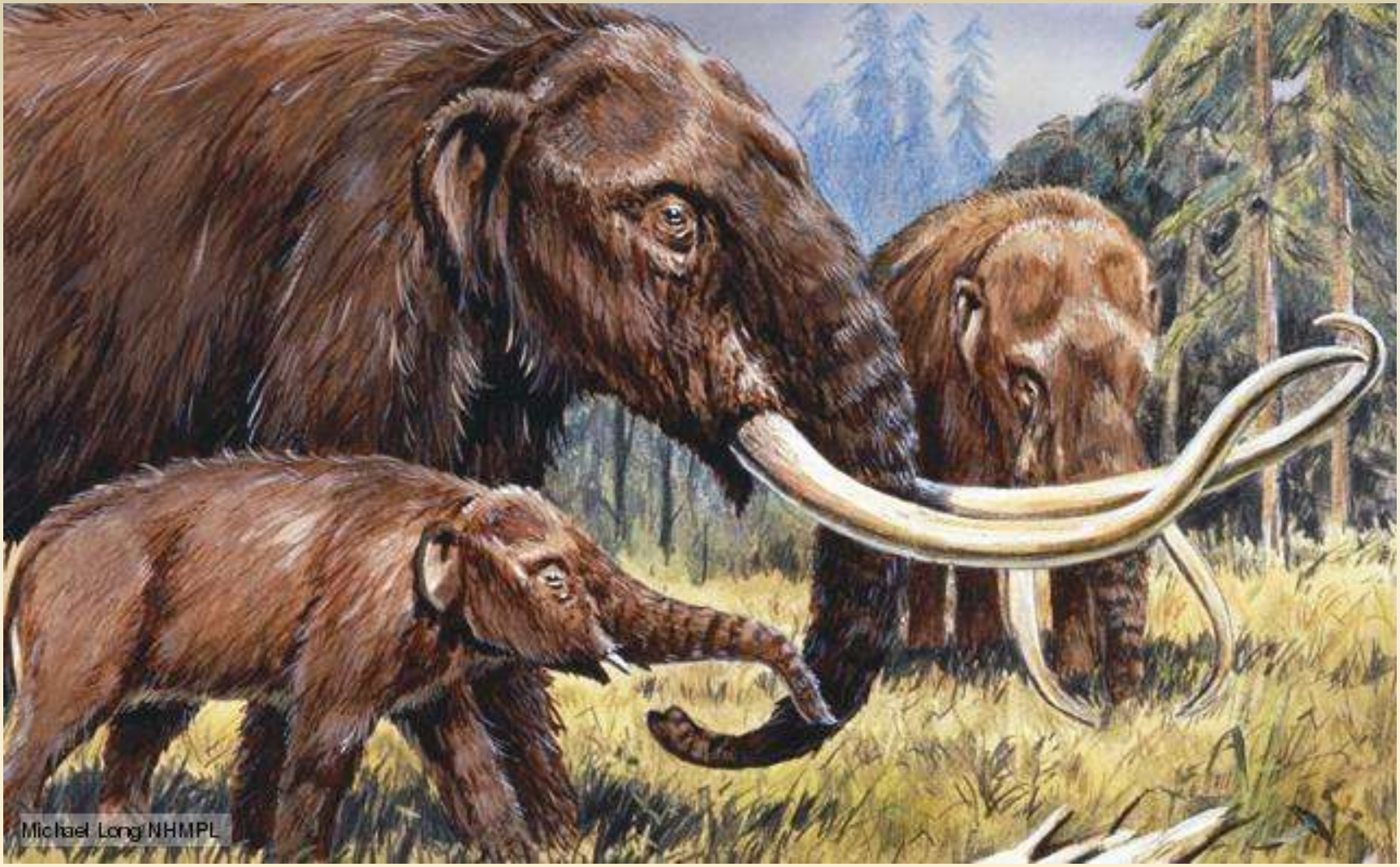

*Smilodon*

# Wooly Rhinoceros

# Wooly Mammoth


Mammuthus primigenius

# Mastodon - *Mammut americanum*



# Mammoths


*Mammuthus*

# Columbian Mammoth


Mammuthus columbi

# Pleistocene Extinctions

- During the Pleistocene,
  - the continental interior of North America
  - was teeming with horses, rhinoceroses, camels,
  - mammoths, mastodons, bison, giant ground sloths,
  - glyptodonts, saber-tooth cats, dire wolves,
  - rodents, and rabbits
- Beginning about 14,000 years ago,
  - many of these animals become extinct,
  - especially the larger ones.

# Lost Genera

- Particularly hard hit were Australia and the Americas
- In Australia, 15 of the continent's 16 genera
  - of large mammals died out,
  - North America lost 33 of 45 large-mammal genera,
  - and in South America 46 of 58 such genera went extinct
- In contrast, Europe lost only 7 of 23 such genera,
  - and in Africa south of the Sahara
  - only 2 of 44 died out

The North American fauna included 31 genera of large mammals.  Only 14 genera remain.

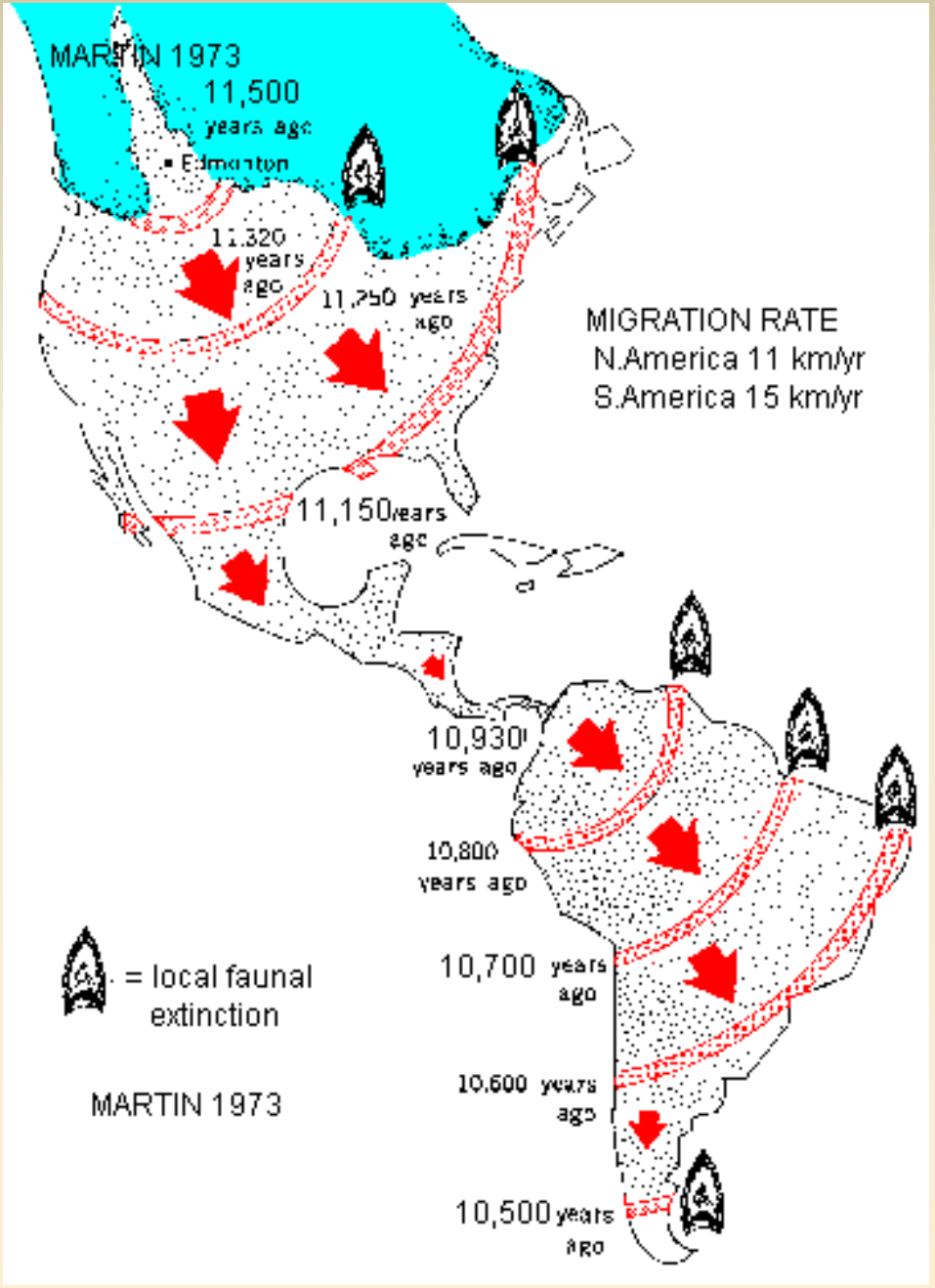
Some 22 genera of birds also disappeared.

# What the heck happened?

Can you name the 14 remaining genera of large, North American mammals?

# Pleistocene Over-kill

Man colonized the Americas from north to south, and the movement seems to have been coupled with local extinctions.



# What Caused the American Mass Extinction?

- Why didn't all Megafauna go extinct?
  - Bison, Pronghorn, Deer, Grizzly Bears
- Did humans really hunt Megafauna?
  - Central Asian Mammoth-bone Huts, but Rabbits Are Main Bones in Food Dumps
  - What killed off Saber-Tooth Cats?
- Did humans kill off some keystone species?
- Timing is sure suspicious

# Holocene - 11.7 thousand years ago to present
# Anthropocene?

# Is There a Potential Sixth Major Mass Extinction?

- Why are species becoming extinct so rapidly?
- Human population growth
- Human impact on the environment
  - Deforestation and Desertification
  - Fragmentation and Destruction of Natural Habitats
  - Contamination of Habitats
    - mining wastes
    - salts from irrigation and aquifer depletions
  - Global Warming

# Global Climate Change

- Increasing global temperatures
- Rising ocean levels as polar ice caps and glaciers melt
- Changing seasonal weather patterns
- More frequent occurrence of weather extremes (e.g., stronger storm systems, increase in droughts & floods)
- Global migration of pathogens and disease vectors (HIV,  malaria, bilharzia, cholera, etc.)



# Human-Caused Holocene (Anthropocene) Extinction

- Human-caused extinctions of the last 10,000 years:
- Excessive Predation (food, fur, collecting, pest eradication, etc.)
- Destruction of keystone species
- Introduction of Exotic Species
  - Competitors, Predators
  - Diseases
  - Exotic Pet Trade
- Air and Water pollution
- Soil and Ocean Pollution

End