Encyclopedia of
Extinct
Animals and Plants

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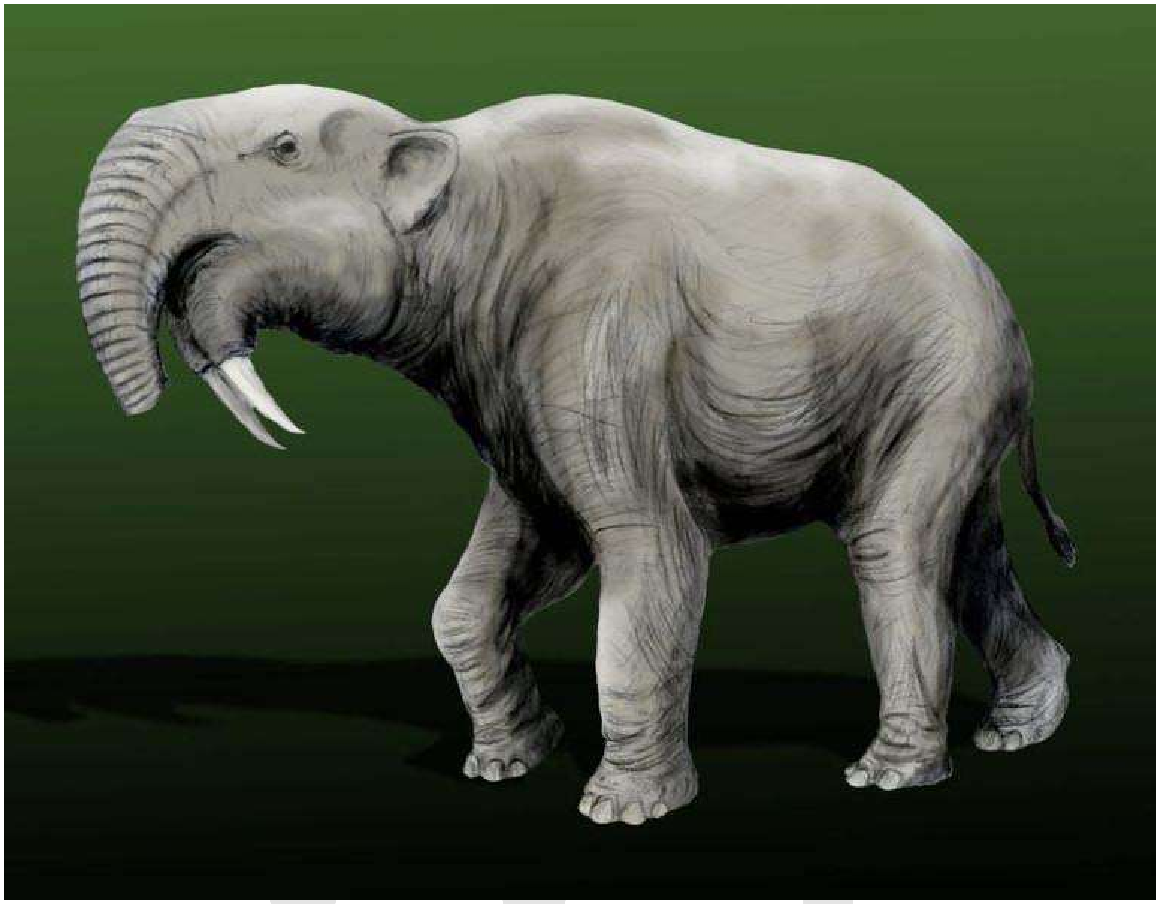
Chapter- 1

Deinotherium

Deinotherium ("terrible beast"), also called the **Hoe tusker**, was a gigantic prehistoric relative of modern-day elephants that appeared in the Middle Miocene and continued until the Early Pleistocene. During that time it changed very little. In life it probably resembled modern elephants, except that its trunk was shorter, and it had downward curving tusks attached to the lower jaw.

Deinotherium is the third largest land mammal known to have existed; only *Paraceratherium* and *Mammuthus sungari* were larger, although *Mammuthus imperator* may have rivaled it in size. Males were generally between 3.5 and 4.5 meters (12 and 15 feet) tall at the shoulders although large specimens may have been up to 5 m (16 ft). Their weight is estimated to have been between 5 and 10 tonnes (5.5 and 11 US Standard tons), with the largest males weighing in excess of 14 tonnes (15.4 US Standard tons). *Deinotherium's* range covered parts of Asia, Africa, and Europe. Adrienne Mayor, in *The First Fossil Hunters: Paleontology In Greek and Roman Times,* has suggested that deinothere fossils found in Greece helped generate myths of archaic giant beings. A tooth of a deinothere found on the island of Crete, in shallow marine sediments of the Miocene suggests that Crete was closer or connected to the mainland during the Messinian Salinity Crisis.

Evolutionary Relationships



Deinotherium giganteum

Deinotherium is the type genus of the family Deinotheriidae, evolving from the smaller, early Miocene *Prodeinotherium*. These proboscideans represent a totally distinct line of evolutionary descent to that of other elephants, one that probably diverged very early in the history of the group as a whole. The large group to which elephants belong formerly contained several other related groups: besides the deinotheres there were the gomphotheres (some of which had shovel-like lower front teeth), and the mastodons. Only elephants survive today.

Paleoecology

The way *Deinotherium* used its curious tusks has been much debated. It may have rooted in soil for underground plant parts like roots and tubers, pulled down branches to snap them and reach leaves, or stripped soft bark from tree trunks. *Deinotherium* fossils have been uncovered at several of the African sites where remains of prehistoric hominid relatives of modern humans have also been found.

Characteristics

Deinotherium skull from Oxford University Museum of Natural History

The following description is for *D. giganteus* but in general applies to the other two species as well.

Permanent tooth formula 0-0-2-3/1-0-2-3 (deciduous 0-0-3/1-0-3), with vertical cheek tooth replacement. Two sets of bilophodont and trilophodont teeth. Molars and rear premolars tapiroid, vertical shearing teeth, and show that deinotheres became an independent evolutionary branch very early on; other premolars used for crushing. The cranium is short, low, and flattened on the top (in contrast to more advanced proboscids, which have a higher and more domed forehead; the implication may be that deinotheres were less intelligent than other proboscids), with very large, elevated occipital condyles. The nasal opening is retracted and large, indicating a large trunk. The rostrum is long and the rostral fossa broad. Mandibular symphyses (the lower jaw-bone) is very long and curved downward, which, with the backward curved tusks, is a distinguishing feature of the group; it possessed no upper tusks.

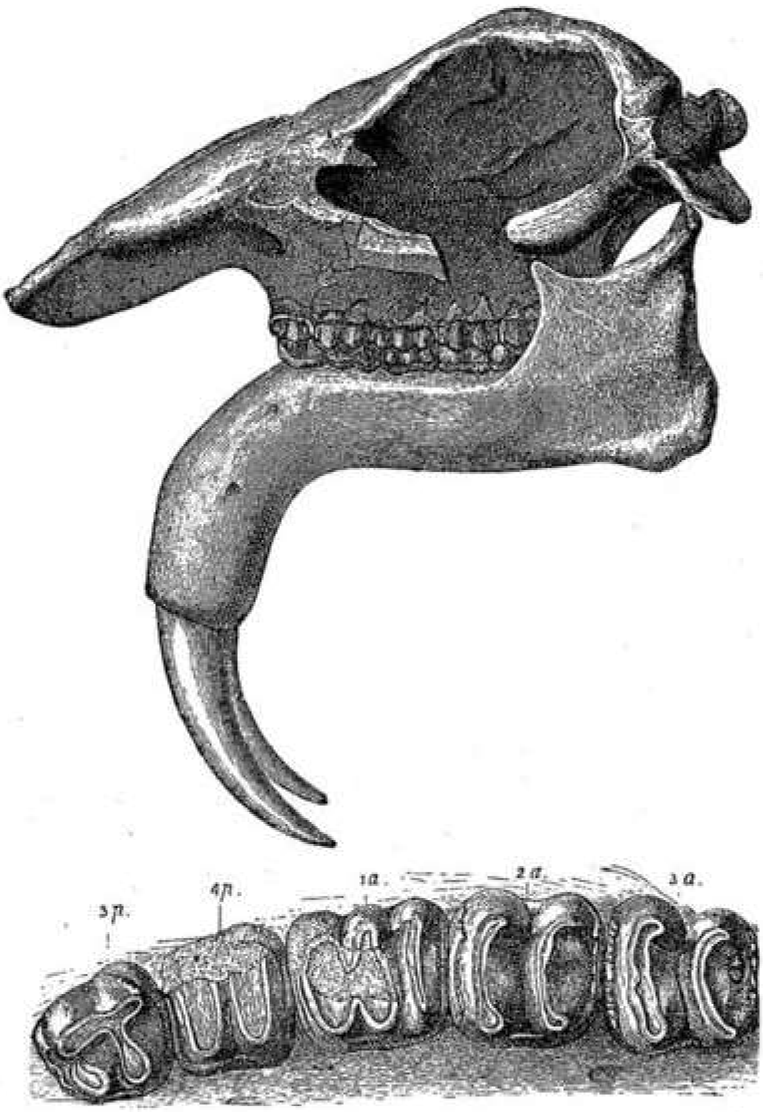
Mounted *Deinotherium* skelton

Deinotherium is distinguished from its predecessor *Prodeinotherium* by its much greater size, greater crown dimensions, and reduced development of posterior cingula ornamentation in the second and third molar.

Species

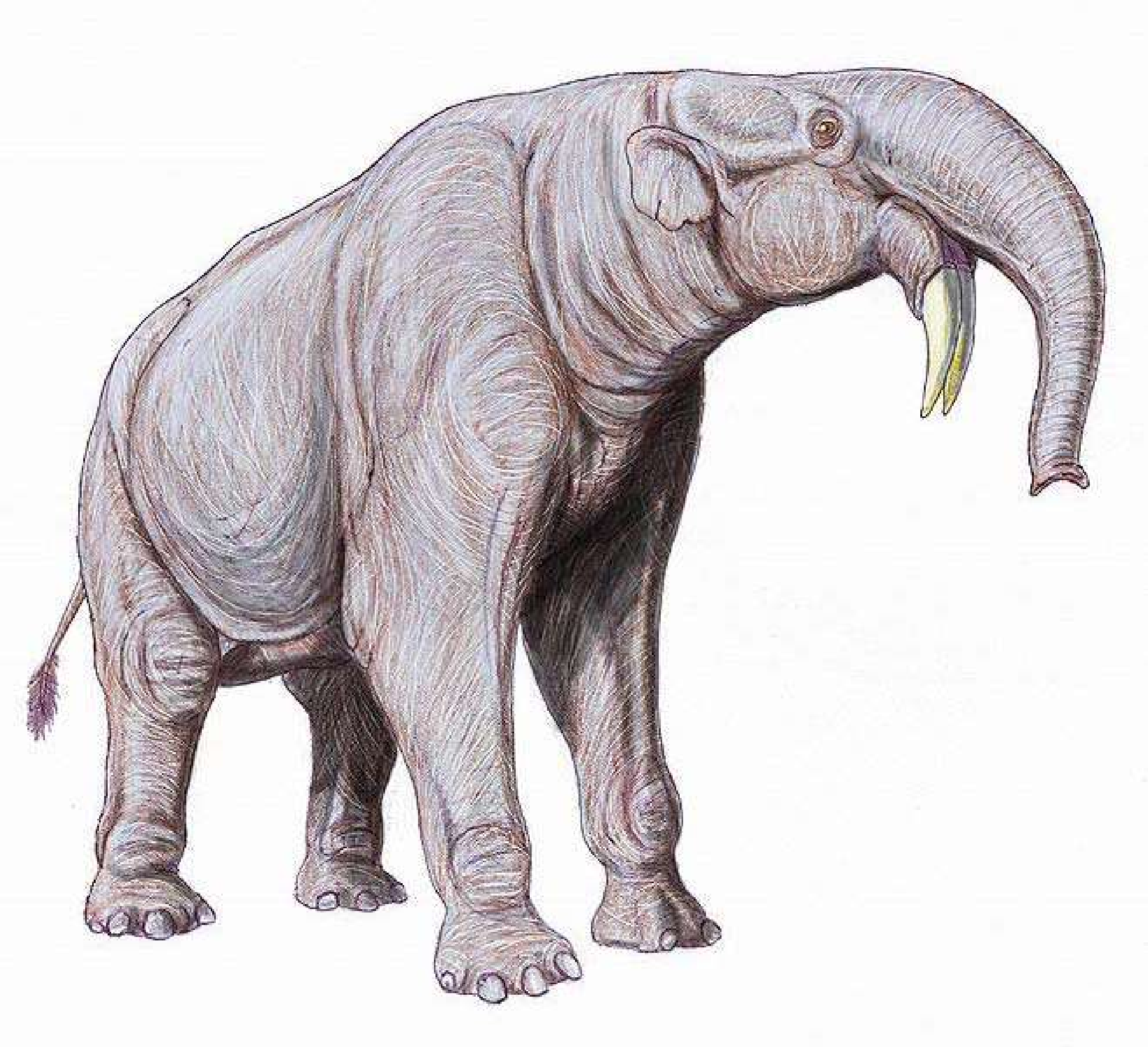
Three species are recognized, all of great size.

Deinotherium giganteum Kaup 1829



Head and teeth of *Deinotherium giganteum*

Deinotherium giganteum is the type species, and is described above. It is primarily a late Miocene species, most common in Europe, and is the only species known from the circum-Mediterranean. Its last reported occurrence is from the middle Pliocene of Romania (2 to 4 million BP). The "Grigore Antipa" museum of natural history in Bucharest, Romania, has the only complete skeleton of Deinotherium giganteum in the world. It was unearthed in 1894, in Vaslui county, by the Romanian paleontologist Gregoriu Stefanescu.



Deinotherium giganteum

An entire skull, found in the Lower Pliocene beds of Eppelsheim, Hesse-Darmstadt in 1836, measured 4 ft (1.2 m) in length and 3 ft (.9 meters) in breadth, indicating an animal exceeding modern elephants in size.

Deinotherium indicum Falconer 1945

Deinotherium indicum is the Asian species, known from India and Pakistan. It is distinguished by a more robust dentition and p4-m3 intravalley tubercles. *D. indicum* appears in the middle Miocene, and is most common in the late Miocene. It disappears from the fossil record about 7 million years BP (late Miocene).

Deinotherium bozasi Arambourg 1934

Deinotherium bozasi is the African species. It is characterized by a narrower rostral trough and smaller but higher nasal aperture, and a higher and narrower cranium, and shorter mandibular symphysis, than the other two species. *D. bozasi* appears at the beginning of the late Miocene, and continues there after the other two species have died out elsewhere. The youngest fossils are from the Kanjera Formation, Kenya, about a million years old (early Pleistocene)

Chapter- 2

Dinofelis

Dinofelis ("terrible cat") is a genus of false sabre-toothed cats belonging to the tribe Metailurini. They were widespread in Europe, Asia, Africa and North America at least 5 million to about 1.2 million years ago (Early Pliocene to Early Pleistocene). Fossils very similar to *Dinofelis* from Lothagam range back to the Late Miocene, some 8 million years ago.

Description and ecology

In size they were between a modern leopard and a lion, most being about the size of a jaguar (70 cm tall and up to 120 kg), medium-sized but powerful cats that possessed two prominent sabre teeth. The front limbs were particularly robust compared to the modern cats (even the jaguar). This stout body may implicate a preference for dense or mixed habitats although it may also have been similar to the extant jaguar with its range from forest to open range including wetland.

Body mass

Two specimens were examined by Serge Legendre and Roth for body mass The first specimen was estimated to have a weight of 31.4 kg (69 lb). The second was estimated to have a weight of 87.8 kg (190 lb).

Dentition

The canine teeth of *Dinofelis* are longer and more flattened than those of modern cats but less so than those of true saber-tooths. *Dinofelis* and other Nimravids are generally referred to as "false saber-tooth" cats because of this. While the lower canines are robust, the cheek teeth are not nearly as robust as those of the lion and other modern big cats.

Fossils

Dinofelis fossils and bones have been found in South Africa along with those of the baboons that it possibly killed. Bones from several specimens of *Dinofelis* and baboons were found in a natural trap. *Dinofelis* may have entered the place to feed on trapped animals or may have simply wandered into a location and was not able to escape again. Several fossils sites from South Africa seem to show that *Dinofelis* may have hunted and killed *Australopithecus afarensis* since they harbored fossilized remains of Dinofelis, hominids, and other large contemporary animals of the period. Also, since *Dinofelis* remains have been found near *Paranthropus* fossil skulls in South Africa, a few of which have peculiar twin holes in their crania matching the *Dinofelis* upper canines's spacing almost exactly, it is possible that *Dinofelis* was preying on robust hominids as well.

It is thought that the gradual disappearance of the forests in which *Dinofelis* hunted may have contributed to its extinction at the start of the ice age.

Diet

Dinofelis hunted animals including, mammoth calves, young and old mastodons, homo habilis (an ancestor of modern humans) and other animals.

Species

Other undescribed species may exist.

- *Dinofelis aronoki* (East Africa) - recently split from *D. barlowi*
- *Dinofelis barlowi* (South Africa)
- *Dinofelis cristata* (China) - includes *D. abeli*
- *Dinofelis darti* (South Africa)
- *Dinofelis diastemata* (Europe)
- *Dinofelis paleoonca* (North America)
- *Dinofelis petteri* (East Africa)
- *Dinofelis piveteaui* (South Africa)
- *Dinofelis* sp. "Langebaanweg"
- *Dinofelis* sp. "Lothagam"

Description of Some Above Species: -

Dinofelis aronoki

Dinofelis aronoki is a member of a Machairodontinae family the true sabre tooths. it lived in Villafranchian and Biharian stage in Kenya and Ethiopia.

Dinofelis barlowi

Dinofelis Barlowi "Barlow's terrible cat" is a probably the smallest subspecies of Dinofelis. It lived during the late Pleistocene in South Africa. It was 70 cm high and 1 m long. like all dinofelis species it belongs to family Machairodontinae "true sabre tooths", tribe Metailurini.

Dinofelis cristata

Dinofelis is an extinct prehistoric saber-toothed cat belonging to the family Felidae endemic to Southern Europe, Africa, and Southwest Asia from the Pliocene to Pleistocene living from 5.3 Ma—11,000 years ago and existed for approximately 5.289 million years. .

Dinofelis darti

Dinofelis darti is a subspecies of dinofelis, a genus of saber-toothed cats, which lived in South Africa during the Villafranchian stage (3.6–1.2 Ma BP) .

Dinofelis paleoonca

Dinofelis paleoonca ("terrible cat") is a genus of saber-toothed cats belonging to the tribe Metailurini of the family *Felidae* endemic to North America during the Pliocene living from 4.9—1.8 mya, existing for approximately 3.1 million years.

Taxonomy

Dinofelis paleoonca was named by Meade (1945) . Its type locality is Meade's Quarry 11, which is in a Blancan terrestrial horizon in the Blanco Formation of Texas. It was recombined as Dinofelis palaeoonca by Kurten (1972), Hemmer (1973), Dalquest (1975), Kurten and Anderson (1980), Schultz (1990) and Werdelin and Lewis (2001).

Morphology

Body mass

Two specimens were examined by Legendre and Roth for body mass The first specimen was estimated to have a weight of 31.4 kg (69 lb). The second was estimated to have a weight of 87.8 kg (190 lb).

Fossil distribution

Three specimens were found in Texas and Washington.

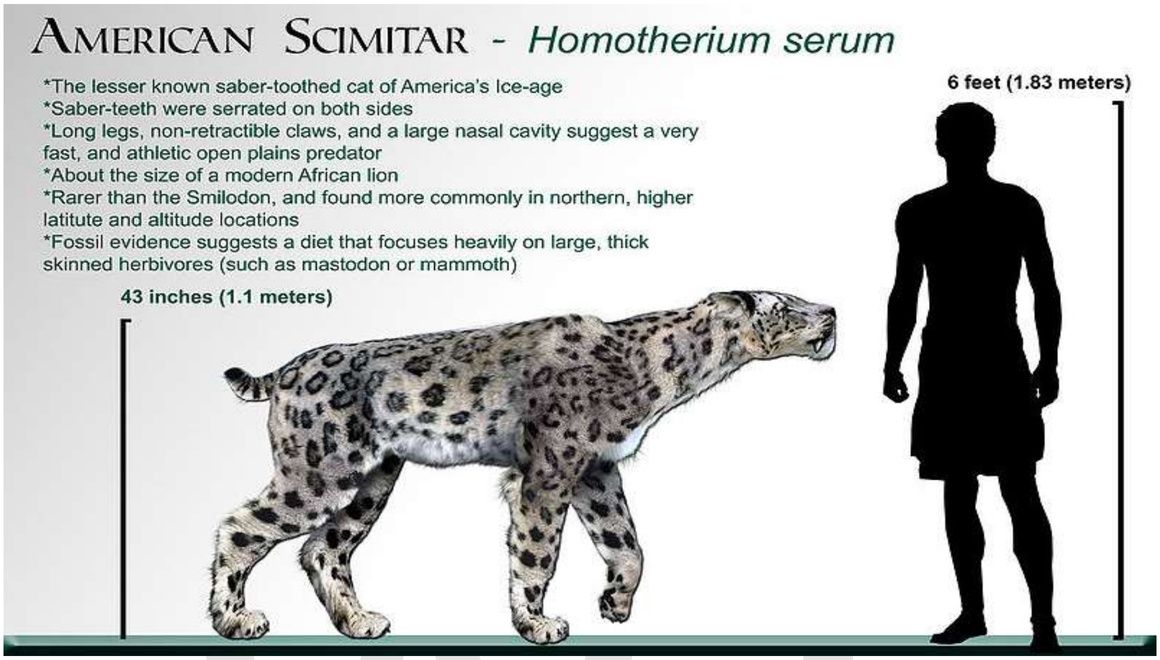
Chapter- 3

Homotherium

Homotherium is an extinct genus of machairodontine saber-toothed cats, often termed **scimitar cats**, endemic to North America, Europe, Asia, and Africa during the Pliocene and Pleistocene epochs (5 mya–10 000 years ago), existing for approximately 5 million years.

It first became extinct in Africa some 1.5 million years ago. In Eurasia it survived until about 30 000 years ago. The last scimitar cat could have survived in North America until 10 000 years ago.

Anatomy


AMERICAN SCIMITAR - *Homotherium serum*

*The lesser known saber-toothed cat of America's Ice-age
*Saber-teeth were serrated on both sides
*Long legs, non-retractible claws, and a large nasal cavity suggest a very fast, and athletic open plains predator
*About the size of a modern African lion
*Rarer than the Smilodon, and found more commonly in northern, higher latitute and altitude locations
*Fossil evidence suggests a diet that focuses heavily on large, thick skinned herbivores (such as mastodon or mammoth)

Homotherium serum life-restoration.

Homotherium serum. a rare felid.

Homotherium reached 1.1 m at the shoulder and was therefore about the size of a lioness, weighing an estimated 190 kg. Compared to some other machairodonts, like *Smilodon* or *Megantereon*, *Homotherium* had relatively shorter upper canines, but they were flat, serrated and longer than those of any living cat. Incisors and lower canines formed a powerful puncturing and gripping device. Among living cats, only the tiger (*Panthera tigris*) has such large incisors, which aid in lifting and carrying prey. The molars of Homotherium were rather weak and not adapted for bone crushing. The skull was longer than in *Smilodon* and had a well-developed crest, where muscles were attached to power the lower jaw. This jaw had down-turned forward flanges to protect the scimitars. Its large canine teeth were crenulated and designed for slashing rather than purely stabbing.

It had the general appearance of a cat, but some of its physical characteristics are rather unusual for a large cat. The limb proportions of *Homotherium* gave it a hyena-like appearance. The forelegs were elongated, while the hind quarters were rather squat with feet perhaps partially plantigrade, causing the back to slope towards the short tail. Features of the hindlimbs indicate that this cat was moderately capable of leaping. The pelvic region, including the sacral vertebrae, were bear-like, as was the short tail composed of 13 vertebrae—about half the number in long-tailed cats.

The unusually large, square nasal opening, like that of the cheetah (*Acinonyx jubatus*), presumably allowed quicker oxygen intake, which aided in rapid running and in cooling the brain. As in the cheetah, too, the brain's visual cortex was large and complex, emphasizing the scimitar cat's ability to see well and function in the day, rather than the night, as in most cats.

Range and species

Homotherium crenatidens skull on display at the Paleozoological Museum of China

Homotherium probably derived from *Machairodus* and appeared for the first time at the Miocene-Pliocene border, about 5 million years ago. During the Pleistocene it occurred in vast parts of Eurasia, North America and until the middle Pleistocene (about 1.5 million years ago) even in Africa. A fossil of *H. crenatidens* was inadvertently dredged from the bed of the North Sea, which was a flat, low-lying extent of marshy tundra laced with rivers during the recent glaciation. There has also been a discovery of 1.8 million-year-old fossils in Venezuela, indicating that scimitar cats were able to invade South America along with *Smilodon* during the Great American Interchange. How long they lasted in South America is not yet evident. *Homotherium* survived in Eurasia and North America until about 30 000 and 10 000 years ago, respectively.

Several species (*H. nestianus*, *sainzelli*, *crenatidens*, *nihowanensis*, *ultimum*) are recognized from Eurasia, which differ mainly in the shape of the canines and in body size. But given the fluctuation range of the size of modern large cats, it is highly probable that all belong to just one species, *Homotherium latidens*.

Two species described form the early Pleistocene of Africa are *Homotherium ethiopicum* and *Homotherium hadarensis*. But they also hardly differ from the Eurasian forms. On the African continent the genus disappeared about 1.5 million years ago. In North America, a very similar species, *Homotherium serum* occurred from the latest Pliocene until the latest Pleistocene. Remains have been found at various sites between Alaska and Texas. In the southern parts of its range the American *Homotherium* co-existed with *Smilodon*; in the northern parts it was the only species of saber-toothed cat. The American *Homotherium* was originally described by the name *Dinobastis*.

Despite *Homotherium*'s vast range and the large amount of fossil remains from Eurasia, Africa and North America, complete skeletons of this cat are relatively rare. One of the most famous sites of *Homotherium* remains is Friesenhahn cave in Texas, where 30 *Homotherium* skeletons were found, along with hundreds of juvenile mammoths and several dire wolves.

Diet and habitat

Skull of *Homotherium serum* from Friesenhahn cave, Texas Memorial Museum, UT Austin, Austin, Texas

Friesenhahn cave in Texas contained the remains of over 30 *H. serum* individuals, which were discovered along with the remains of between 300 and 400 juvenile Columbian Mammoths (*Mammuthus columbii*). Besides mammoth, very few other potential prey species were found in the cave - it is therefore unlikely that *Homotherium* carried scavenged carcasses of already dead animals to the cave. Such specialization on prey of a particular species and age structure is not covenant with a scavenging lifestyle. For the same reason it is also unlikely that the dire wolves carried the mammoths into the cave.

Homotherium crenatidens skull

The worldwide association of *Homotherium* species with proboscidean (elephant and mastodon) and Rhinoceros remains, mainly those of juveniles, suggests that *Homotherium* preyed selectively on these tough-skinned animals and probably hunted in packs, carrying away the large animals it brought down. The decline of *Homotherium* could be due to the disappearance of large herbivorous mammals like mammoths in America at the end of the Pleistocene. In North America fossil remains of *Homotherium* are less abundant than those of its contemporary *Smilodon*. For the most part it probably inhabited higher latitudes and altitudes, and therefore was likely to be well adapted to the colder conditions of the mammoth steppe environment.

The suggested large prey species make it probable that *Homotherium* hunted in packs. Reduced claws, relatively slender limbs and the sloping back indicate adaptations for endurance running in open habitats.

Chapter- 4

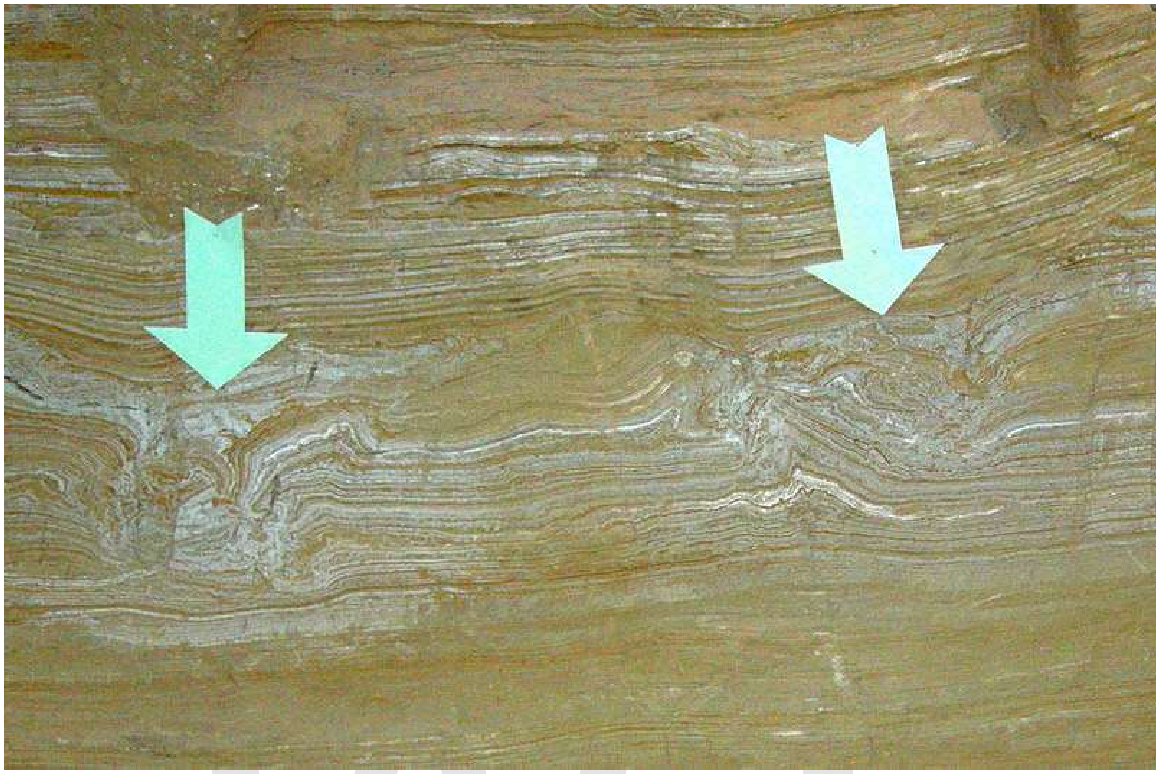
Mammoth

A **mammoth** is any species of the extinct genus ***Mammuthus***. These proboscideans are members of Elephantidae, the family of elephants and mammoths, and close relatives of modern elephants. They were often equipped with long curved tusks and, in northern species, a covering of long hair. They lived from the Pliocene epoch from around 4.8 million to 4,500 years ago. The word *mammoth* comes from the Russian мамонт *mamont*, probably in turn from the Vogul (Mansi) language, *mang ont*, meaning "earth horn".

Size

Like their modern relative the elephant (Asian or African), mammoths were quite large; in English the noun "mammoth" has become an adjective meaning "large" or "massive". The largest known species, Songhua River mammoth (*Mammuthus sungari*) , reached heights of at least 5 metres (16 feet) at the shoulder. Mammoths would probably normally weigh in the region of 6 to 8 tons, but exceptionally large males may have exceeded 12 tons. However, most species of mammoth were only about as large as a modern Asian elephant. Fossils of species of dwarf mammoth have been found on the Californian Channel Islands (*Mammuthus exilis*) and the Mediterranean island of Sardinia (*Mammuthus lamarmorae*). There was also a race of dwarf woolly mammoths on Wrangel Island, north of Siberia, within the Arctic Circle.

A full size reconstruction of a mammoth species, the woolly mammoth, at Ipswich Museum, Ipswich, Suffolk



Cross-section of mammoth footprints (a type of trace fossil) at the Hot Springs Mammoth Site in South Dakota

An 11-foot (3.4 m) long mammoth tusk was discovered north of Lincoln, Illinois in 2005.

Based on studies of their close relatives the modern elephants, mammoths probably had a gestation period of 22 months, resulting in a single calf being born. Their social structure was probably the same as that of African and Asian elephants, with females living in herds headed by a matriarch, whilst bulls lived solitary lives or formed loose groups after sexual maturity.

Well-preserved specimens and prospects of cloning

In May 2007, the carcass of a one-month-old female woolly mammoth calf was discovered in a layer of permafrost near the Yuribei River in Russia, where it had been buried for 37,000 years. Alexei Tikhonov, the Russian Academy of Science's Zoological Institute's deputy director, has dismissed the prospect of cloning the animal, as the whole cells required for cloning would have burst under the freezing conditions. Nonetheless, DNA is expected to be well-enough preserved to be useful for research on mammoth phylogeny and perhaps physiology. However, Dr Sayaka Wakayama from the RIKEN Center for Developmental Biology in Kobe, Japan, believes that a technique she has used to clone mice from specimens frozen for sixteen years could be used successfully on recovered mammoth tissue: she cites that in her experiments the dead mice had been frozen to -20°C under simulated natural conditions, without using the usual preservative chemicals.

Researchers at Penn State University have sequenced about 85% of the gene map of the woolly mammoth, using DNA taken from hair samples collected from a selection of specimens, advancing the possibility of bringing the woolly mammoth back to life by inserting mammoth DNA sequences into the genome of the modern-day elephant, transferring it into an egg cell and, in turn, into the uterus of an elephant as a variant of interspecific pregnancy. Although the samples were washed with bleach to remove possible contamination by bacteria or fungi, some DNA bases identified may be from the contaminating organisms and these have yet to be distinguished. To this end, scientists at the Broad Institute are currently generating a comparison with the genome of the African elephant. The information cannot be used to synthesize mammoth DNA, but Dr Stephan Schuster, leader of the project, notes that the mammoth's genes differ at only some 400,000 sites from the genome of the African elephant and it would be possible (though not with presently available technology) to modify an elephant cell at these sites to make it resemble one bearing a mammoth's genome, and implant it into a surrogate elephant mother.

There is an estimate of 150 million mammoth remains in Russia's Siberian permafrost, which covers a vast sparsely inhabited area. Some of the remains are frozen complete, others in pieces of bone, tusk, tissue and wool, from less than a metre (3.3 ft) to 1 km (3300 ft) below ground.

Extinction

Mammuthus armeniacus skull

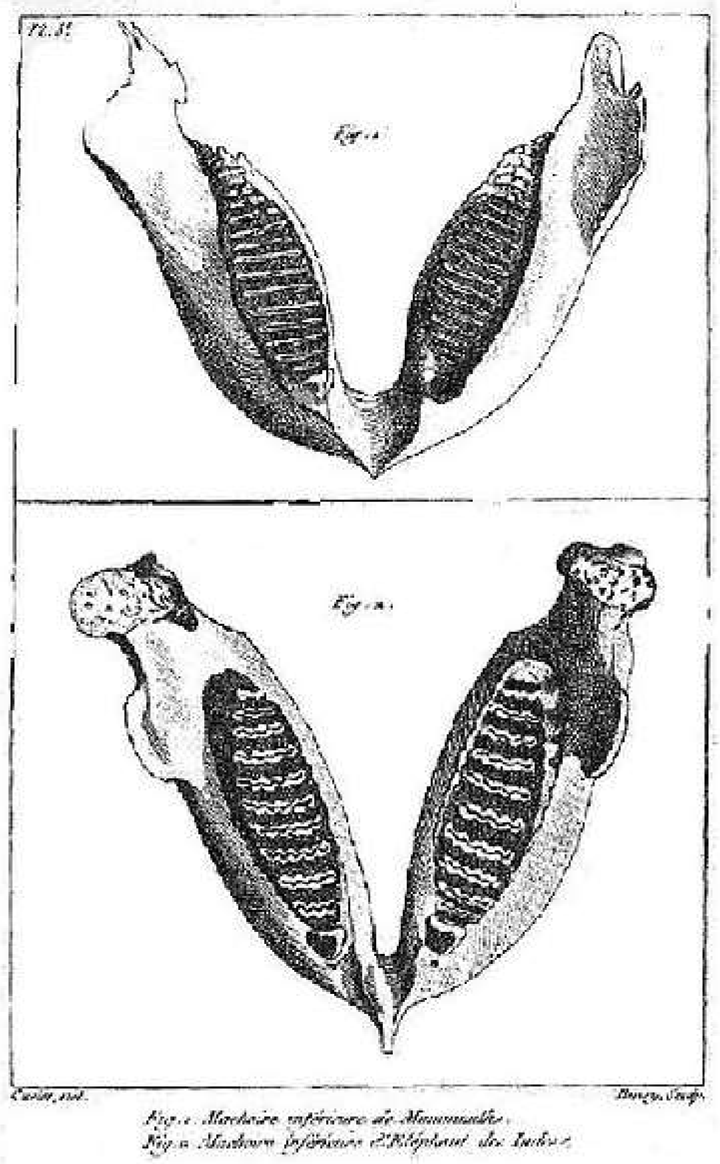
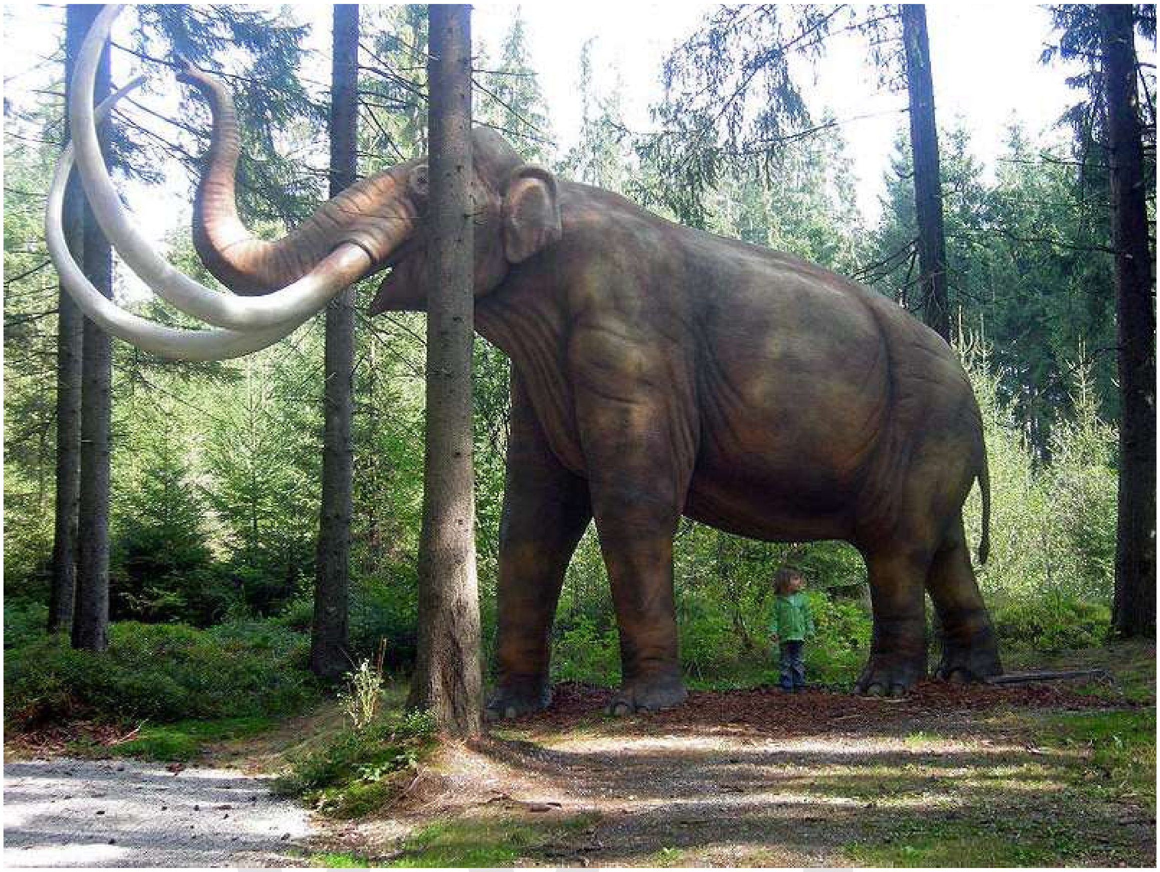


Illustration of an Indian elephant jaw and a mammoth jaw from Georges Cuvier's 1796 paper on living and fossil elephants.



Full size life reconstruction of a mammoth (*Mammuthus trogontherii*).

The woolly mammoth was the last species of the genus. Most populations of the woolly mammoth in North America and Eurasia, as well all the Columbian mammoths in North America, died out around the time of the last glacial retreat, as part of a mass extinction of megafauna in northern Eurasia and the Americas. Until recently, it was generally assumed that the last woolly mammoths vanished from Europe and southern Siberia about 10,000 BC, but new findings show that some were still present there about 8000 BC. Only slightly later, the woolly mammoths also disappeared from continental northern Siberia. A small population survived on St. Paul Island, Alaska, up until 3,750 BC, and the small mammoths of Wrangel Island survived until 1,650 BC.

A definitive explanation for their mass extinction is yet to be agreed upon. The warming trend (Holocene) that occurred 12,000 years ago, accompanied by a glacial retreat and rising sea levels, has been suggested as a contributing factor. Forests replaced open woodlands and grasslands across the continent. The available habitat may have been reduced for some megafaunal species, such as the mammoth. However, such climate changes were nothing new; numerous very similar warming episodes had occurred previously within the ice age of the last several million years without producing comparable megafaunal extinctions, so climate alone is unlikely to have played a decisive role. The spread of advanced human hunters through northern Eurasia and the Americas around the time of the extinctions *was* a new development, and thus probably contributed significantly.

Whether the general mammoth population died out for climatic reasons or due to overhunting by humans is controversial. Another theory suggests that mammoths may have fallen victim to an infectious disease. A combination of climate change and hunting by humans has been suggested as the most likely explanation for their extinction.

Data derived from studies done on living elephants suggest human hunting was likely a strong contributing factor in the mammoth's final extinction . *Homo erectus* is known to have consumed mammoth meat as early as 1.8 million years ago.

However, the American Institute of Biological Sciences also notes bones of dead elephants, left on the ground and subsequently trampled by other elephants, tend to bear marks resembling butchery marks, which have previously been misinterpreted as such by archaeologists .

The survival of the dwarf mammoths on Russia's Wrangel Island was due to the island's very remote location and lack of inhabitants in the early Holocene period . The European discovery of the island (by American whalers) did not occur until the 1820s . A similar dwarfing occurred with the pygmy mammoth on the outer Channel Islands of California, but at an earlier period. Those animals were very likely killed by early Paleo-Native Americans, and habitat loss caused by a rising sea level that split Santa Rosae into the outer Channel Islands .

Recent research indicates that mammoths survived on the American mainland until 10,000 years ago. This conclusion is from research, by James Haile and Eske Willerslev of the University of Copenhagen, of sediments found in central Alaska, and reported in the Proceedings of the National Academy of Sciences.

Chapter- 5

Megantereon

Megantereon was an ancient machairodontine saber-toothed cat that lived in North America, Eurasia, and Africa. It may be the ancestor of *Smilodon*.

Fossil range

Fossil fragments have been found in Africa, Eurasia, and North America. *Megantereon* seems to have first appeared in the early Late Miocene roughly 11.61—5.33 million years ago with fossil evidence of *M. praecox* recovered in Punjab, Pakistan. In North America, the oldest specimen was *M. hesperus* unearthed in Polk County, Florida, USA dating to 7.9—-7.8 Ma (AEO).

About 3-3.5 Million years ago it is firmly recorded also from Africa and Eurasia. At the end of the Pliocene it evolved into the larger *Smilodon* in North America, while it survived in the Old World until the middle Pleistocene. The youngest remains from east Africa are about 1.5 million years old. In southern Africa the genus is recorded from Elandsfontein, a site dated to around 700,000-400,000 years old. Remains from Untermaßfeld show that *Megantereon* lived until 900,000 years ago in Europe. In Asia it may have survived until 500,000 years ago, as it is recorded together with *Homo erectus* at the famous site of Zho-Khou-Dien in China. The only full skeleton was found in Senéze, France.

Morphology

Megantereon was built like a modern jaguar or somewhat heavier. It had stocky forelimbs with the lower half of these forelimbs lion-sized. It had large neck muscles designed to deliver a powerful bite. The elongated upper canines were protected by flanges at the mandible. Mauricio Anton's reconstruction in *The big cats and their fossil relatives* depicts the full specimen found at Seneze in France as 72 centimetres (28 in) at the shoulder. The largest specimens with an estimated body weight of 90–150 kilograms (200–330 lb) (average 120 kilograms (260 lb)) are known from India. Medium sized species of *Megantereon* are known from other parts of Eurasia and the Pliocene of North America. The smallest species from Africa and the lower Pleistocene of Europe have been estimated to only 60–70 kilograms (130–150 lb). However, other sources estimated *Megantereon* from the European lower Pleistocene at 100–160 kilograms (220–350 lb).

Hunting technique

It is unlikely that *Megantereon* simply bit its prey as the long, sabre-teeth that *Smilodon* is famed for are not strong enough to leave buried inside a struggling prey animal: the teeth would break off. It is possible that they bit their prey and then allowed it to bleed to death, but then they would have to protect that animal from other predators and thus their tactic for killing remains uncertain. It is now generally thought that *Megantereon*, like other saber-toothed cats, used its long saber teeth to deliver a killing throat bite, severing most of the major nerves and blood vessels. While the teeth would still risk damage, the prey animal would be killed quickly enough that any struggles would be feeble at best.

Species

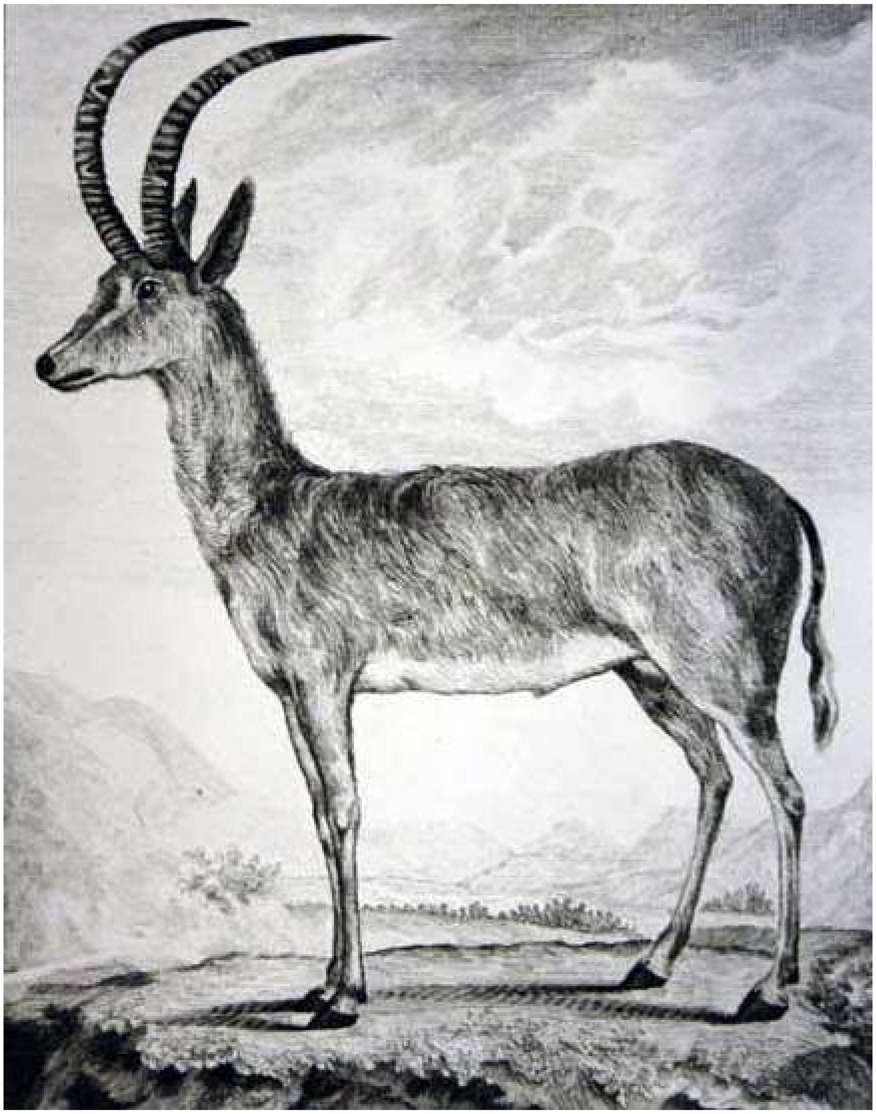
The number of species is unclear, with some known from only fragmentary evidence. Some researchers have argued that three species should be distinguished: *M. cultridens* from North America, Asia (except the Indian subcontinent) and the European Pliocene, *M. whitei* from Africa and the European Lower Pleistocene and *M. falconeri* from India.

Therefore, the true number of species may be less than the full list of described species reproduced below.

- *Megantereon nihowanensis* - probably a junior synonym of *M cultridens*
- *Megantereon cultridens*
- *Megantereon whitei*
- *Megantereon gracile*
- *Megantereon eurynodon*
- *Megantereon megantereon*
- *Megantereon vakhshensis*
- *Megantereon ekidoit*
- *Megantereon falconeri*
- *Megantereon hesperus*
- *Megantereon spiryleris*

Chapter- 6

Bluebuck



The **Bluebuck** or **Blue Antelope** (*Hippotragus leucophaeus*), sometimes called **Blaubok**, is an extinct species of antelope, the first large African mammal to disappear in historic times. It is related to the Roan Antelope and Sable Antelope, but slightly smaller than either. It lived in the southwestern coastal region of South Africa savannahs, but was more widespread during the last glacial. It was probably a selective feeder, preferring high-quality grasses.

Europeans encountered the Bluebuck in the 17th century, but it was already uncommon by then. European settlers hunted it avidly, despite its flesh being distasteful, while converting its habitat to agriculture. The Bluebuck became extinct around 1800. There are only four mounted specimens – in museums in Vienna, Stockholm, Paris, and Leiden – along with some bones and horns elsewhere. None of the museum specimens show a blue colour, which may have derived from a mixture of black and yellow hairs.

Characteristics

Illustration of a Bluebuck and a Klipspringer from 1851.

Total length: 250–300 cm (8.2–9.8 ft) (bull); 230–280 cm (7.5–9.2 ft) (cow)

Shoulder height: 100–120 cm (3.3–3.9 ft)

Skull length: 396 mm (15.6 in)

Horn length: 50–61 cm (20–24 in)

Body mass: 160 kg (350 lb)

Eighteenth century travellers provided contradictory descriptions of this species, perhaps because some were embellishing, while others had not actually seen it and were simply repeating hearsay - Peter Kolb in 1719 incorrectly described it as having a long goat-like beard and tail, straight horns like an oryx, and short ears . They did send some skulls and skins back to Europe. In 1967, Erna Mohr reported that the four existing mounted blue antelopes vary from 102 to 116 cm (3.35 to 3.81 ft) at the shoulder. Adult Bluebuck probably rarely exceeded 160 kg (350 lb). None of the four museum specimens show any sheen of blue. The dark skin showing through the thinning fur of older animals may have caused the blue colours described by several authors or the mix of black and yellow hairs.

Like most antelopes, the Bluebuck had six teeth along the cheek in each half of the upper and lower jaws. These formed two distinct series three premolars immediately followed by three molars. Its remains can be distinguished from those of the roan by smaller molars and premolars, and from the sable by larger premolars, and a higher ratio of premolar row length to molar row length.

The Bluebuck was a large, horse-like antelope, as heavy as a Javan or English horse, but smaller than the roan or sable. The proportions of its body were similar to that of the southern reedbuck .

It had a relatively long, strong neck with a very short, underdeveloped mane , long white legs with dark bands on the anterior, and a long tail, up to the hock, with a dark, horse-like whisk. It had a long muzzle. Its ears were long and donkey-like, rufous and narrow-pointed, without the black tufts of hair found in the roan.

The long, scimitar-shaped horns inserted directly above the orbits, extending upwards at almost right angles to the skull , and then curving back gently, without any torsion, towards the shoulders . These horns were heavily ridged, with 20-35 rings up to the tip of the horn, comparable to the roan (20-50 rings). Its horns were however more lightly built than those of the roan and sable, and slightly transversely compressed to the inside. The back-curved horns reminded Jan van Riebeeck of the European ibex, and he called it the 'steinbok'. It remains uncertain how long this name was used, or when it was changed to 'blaauwbok' or Bluebuck.

Its hair was short and glossy, and of a delicate light blue to grey - which quickly faded to a bluish grey after death. Its belly was pale white, and didn't actually contrast with the colour of the flanks. Its forehead and the upper muzzle was brown, becoming lighter towards the cheeks and upper lips. It had distinct white patches in front of the eyes not reaching the white muzzle.

The bulls resembled the cows up to the age of three years, after which they became paler (almost white) and developed large, more curved horns; the horns of the cows where more or less of the same length, although thinner and 10-20% smaller. The calves younger than 2 months were light tan, with no or very indistinct markings.

Range

When the Europeans settled in the Cape Colony in the 17th and 18th century, they found the Bluebuck on the coastal plains of the southwestern Cape Province , east of the Hottentots Holland mountains. It was never very common, and was probably restricted to a grassland area of less than 4 000 km^2 in the triangle formed by the towns of Caledon, Swellendam and Bredasdorp, South Africa. Lieutenant W.J. St. John also recorded 'roans' of a bluish grey colour at Liebenbergsvlei (28º15'S, 28º29'E) near Bethlehem in the Free State Province on 28–29 July 1853, and it is now thought that he actually saw the last remnants of a relict population of Bluebuck.

From archaeological and palaeontological evidence it is known that the Bluebuck had a wider distribution, and was more common, during the early Holocene Epoch 10,000 years ago. At one time it could be found on the coastal plain of the Cape Province from Elands Bay in the northwest to Uniondale in the east. Researchers of the National Museum in Bloemfontein have found San (Bushman) rock paintings near Ficksburg and Golden Gate Highlands National Park , while Pleistocene deposits (100 000 to 10 000 years ago) confirm its existence at Rose Cottage cave near Ladybrand .

Habitat

The early travellers found the Bluebuck only in rolling grassland with extensive marshes and open areas with medium to long (0,5-1,5 m), perennial tuft grass and little hillside shrub. It was also at home at higher elevations, up to 2 400 m above sea-level. It was susceptible to droughts, and water was a necessary habitat requirement.

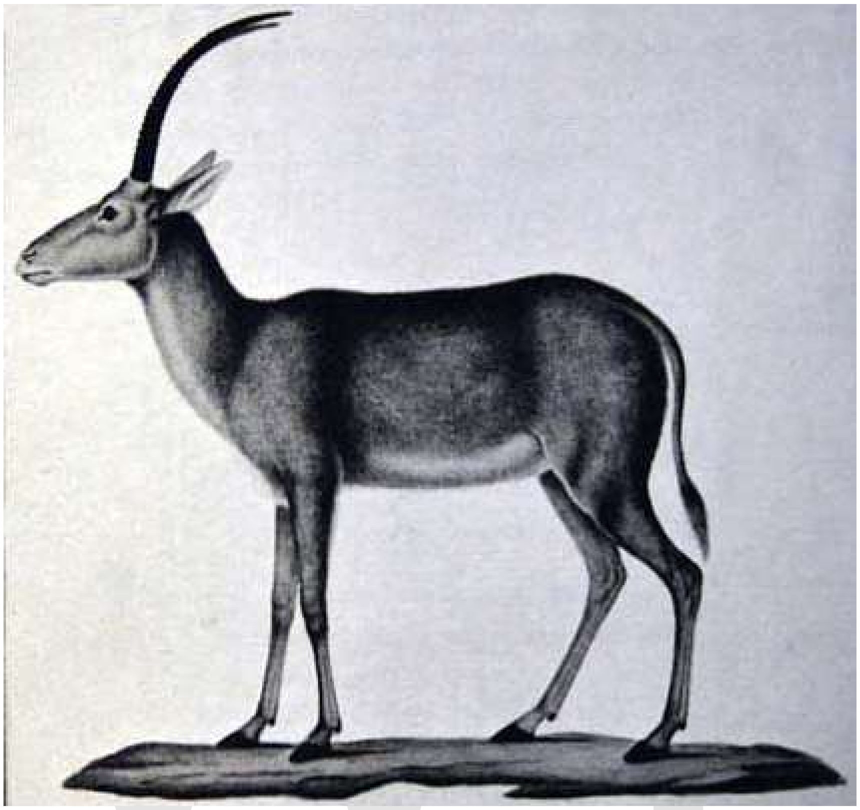
They avoided areas with short grass and woodland where trees formed a thick canopy or thickets. Habitat change, due to overgrazing of grassland by other species, like sheep, thus threatened this species.

Food

Like the roan and sable, it had to drink daily. Many other antelopes can obtain the moisture they need from the plants they eat and they can go for long periods without drinking.

The Bluebuck was a selective grazer of medium to long (0.5-1.5 m), perennial tuft grasses, like high-quality red grass (*Themeda triandra*), spear grass (*Heteropogon contortus*), buffalo grass (*Panicum* spp.) and love grass (*Eragrostis* spp.). Unlike most other antelope, it was not particularly attracted to fresh grass, except during the dry season, when it would graze for short periods along drainage-lines and on floodplains on the fresh growth following the yearly fires. However, like most grazers, it would probably browse during the dry season.

Behavior



Drawing from 1781, by Le Vaillant

Most of its activities took place during the day, especially early in the morning and late in the afternoon.

Bluebucks followed the conventional territorial system among the Hippotragini or 'horse antelopes': territorial bulls, herds of cows and calves, and bachelor herds which were kept segregate by the territorial bulls.

Bluebuck cows and calves lived in small to medium-sized herds of 5 to 20 individuals, although herds of 35 to 80 was not unusual. They normally occurred at a low density of about 4/km^2. Cows shared a traditional home range, which included the territories of several bulls and occupied it for up to 30 years. At very low densities in substandard habitat the cows ranged across larger areas, and were accompanied by the same bull, which in the absence of resistance by territorial neighbours, defended a movable space around his own private harem.

Because they were equipped with long, dangerous horns, cows tended to be more aggressive than those antelope whose females are hornless. Dominance hierarchies based on age and individual prowess were vigorously maintained by both sexes. Maternal herds, composed of animals that shared the same home range, were closed to outsiders. Herd members kept out of range of each other's horns, by increasing the individual space between them.

Herd composition changed daily and seasonally; members split into small groups during the rainy season, and concentrated into larger groups on the best available grazing near water during the dry season. The most cohesive groups were maintained by calves of different ages, which clustered around the youngest calf and usually lagged behind the herd.

Bulls were accepted in the natal herd up to the age of 15–18 months, which was unusually long. Until then, their similarity to cows suppressed the aggression of the territorial bulls. Subadult bulls were driven from the herd, and if these juveniles didn't escape quickly enough, they were killed. They then joined bachelor herds, where they stayed until they reached five or six years of age, when they would be strong enough to defend their own territory.

The adult bull would advertise his presence and high social status by standing or lying alone or away from the herd, at a conspicuous place. The bull stood in an erect manner, which was a sign of high status, and it was self-advertising if it was not directed. When another bull approached his herd, the dominant bull would stand with his neck arched, head high, and ears turned sideways. Unless the intruder showed submission by lowering his head, the bull kept his ears erect, and waved his tail or tucked it between his legs, and a clash of horns and head-butting would take place. Its sound was a blowing snort.

Reproduction

One calf, with a birth mass of 12–14 kg, was dropped after a gestation period of 268–281 days at any time of the year, with a peak during late summer. Bluebuck are thought to have lived for up to 18 years.

Predators

The calves were vulnerable to attacks from spotted hyenas (*Crocuta crocuta*), leopards (*Panthera pardus*) and wild dogs (*Lycaon pictus*). The adults were large and formidable, and resistant to predation in areas with low predator densities. They did sometimes fall prey to lions (*Panthera leo*), but were attacked with caution. Normally they would flee from predators, but when wounded, a bluebuck would lay down, preferably in a marsh, and defended itself with its razor-sharp horns - the angle-horn threat display indicating that it intended to stab sideways or over its shoulder.

History and population

The Bluebuck or Blue Antelope was the first large African mammal to become extinct in historical times.

Shortly after the last Ice Age, about 10 000 years ago, the Bluebuck must have been common in the far south of Africa, which was largely covered with grassy plains. Numerous finds of subfossil bones indicate a former distribution area from Elands Bay in the present Cape Colony to about 25° E at Uniondale, as well as in the Eastern Free State. Bluebuck numbers dropped about 3 200-2 000 years ago, due to the change of grassland into bush and forest when the climate became warmer.

They showed a sharp decline around 400 A.D., which coincided with the introduction of livestock, particularly sheep, by man at about that time. Competition for grazing with sheep, the resulting habitat degradation due to overgrazing, and diseases may all have contributed to a decline in Bluebuck. Subsistence hunting could also have played a role - it is known that the Late Stone Age inhabitants of Rose Cottage cave hunted several game species, including Bluebuck. To the San (Bushman) the Bluebuck was an important animal, since rock art indicates that these animals contained supernatural power.

Jan van Riebeeck mentioned a "steinbok" or ibex with back-curved horns near Cape Town, while the German Peter Kolb was the first to write about the existence of a "blaauwbok" or Bluebuck in 1719. The Bluebuck was clearly on its way to extinction when European naturalists and hunters finally discovered it. Its range was already small when Europeans who settled in the Cape Colony in the 17th and 18th century first saw this antelope. The Swedish naturalist Carl Peter Thunberg noted in 1774 that these animals were becoming rare. European hunters and farmers hunted it mainly for its skin. Its meat was not fatty, and generally fed to the dogs, although it was just as tasty as that of deer. According to the German zoologist Martin Lichtenstein, the last Bluebuck in the Cape Province was killed in 1799/1800 in the Swellendam district. However, there is good evidence to suggest that an isolated remnant population still existed further north in the 18th century, and that the last Bluebuck died in the Eastern Free State more than fifty years later.

Extinction

A Bluebuck on display in the Naturhistorisches Museum Wien.

Cultivation of the Cape Colony and hunting with firearms quickly destroyed the last small herds. The Bluebuck disappeared before the early natural history cabinets and museums had a chance to obtain a fair number of specimens.

Museum specimens

There are four mounted Bluebuck skins: in the National Museum of Natural History "Naturalis" in Leiden (the Netherlands), and in the natural history museums of

Stockholm (Sweden), Paris (France) and Vienna (Austria). Not counting the many bones excavated throughout the species' former range, there are two skulls, in Amsterdam (the Netherlands) and Glasgow (United Kingdom), and three pairs of horns, in Uppsala (Sweden), London (United Kingdom) and Cape Town (South Africa). None of these specimens are properly documented. .

Relatives

Two close relatives of the Bluebuck are the roan antelope (*Hippotragus equinus*) and the sable antelope (*Hippotragus niger*). Although some naturalists in the past classified the Bluebuck merely as a subspecies of the roan, it is now generally accepted as a separate species. This is based on the fact that Bluebuck and roan occurred in sympatry on the coastal plain of the southwestern Cape from Oakhurst to Uniondale during the early Holocene.

There were a lot of speculations that the Giant or Giant Sable Antelope (*Hippotragus niger variani*) had become extinct. There had been unconfirmed sightings in recent years, but no confirmed sightings for 20 years. This subspecies of the Sable Antelope only occurred in Angola, and there are no specimens present in zoos.

An expedition headed to Angola on 14 August 2002 to search for the giant sable antelope. The expedition had tried hunting for the antelope by helicopter, but the animals avoid sound at all costs. Interviews with tribal chiefs revealed that locals often sighted the animals in the Luando reserve, so the expedition changed tactics and carried out ground surveys on foot. They recorded five separate sightings but were not able to take any photographs. These five animals were spotted in Cangandala National Park in Malanje province in north-central Angola by a team led by Professor Wouter van Hoven of the University of Pretoria.

Chapter- 7

Cave Bear

The **Cave Bear** (*Ursus spelaeus*) was a species of bear which lived in Europe during the Pleistocene and became extinct at the beginning of the Last Glacial Maximum about 27,500 years ago. Both the name *Cave Bear* and the scientific name *spelaeus* derive from the fact that fossils of this species were mostly found in caves, indicating that this species spent more time in caves than the Brown Bear, which only uses caves for hibernation. Consequently, in the course of time, whole layers of bones, almost entirely those of cave bears, were found in many caves.

History of cave bear discoveries

Rearing *Ursus spelaeus* skeleton

Cave bear skeletons were first described in 1774 by Johann Friederich Esper in his book *Newly Discovered Zoolites of Unknown Four Footed Animals*. Originally thought to belong to dragons, unicorns, apes, canids or felids, Esper postulated that they actually belonged to polar bears. Twenty years later, Johann Christian Rosenmüller, an anatomist at the Leipzig University, gave the species its binomial name. Cave bear bones were so numerous that most researchers held little respect for them. During World War I, large amounts of cave bear bones were used as a source of phosphates, leaving behind little more than skulls and leg bones.

Many caves in Europe have skeletons of cave bears on display, for example the *Heinrichshöhle* in Hemer or the *Dechenhöhle* in Iserlohn, Germany. In Romania, there is a cave called Peştera Urşilor (Bears' Cave) where 140 cave bear skeletons were discovered in 1983.

Description and Biology

Range and habitat

The cave bear's range stretched across Europe, from Spain to Eurasia, from Italy and Greece to Belgium, the Netherlands and possibly Great Britain, across a portion of Germany through Poland, then south into Hungary, Romania and parts of Russia, Caucasus and northern Iran. There have been no traces of cave bears living in northern Britain, Scandinavia or the Baltic countries, which were covered in extensive glaciers at the time. The largest numbers of cave bear remains have been found in Austria, Switzerland, southern Germany, northern Italy, northern Spain, Croatia, Hungary, and Romania. The huge number of bones found in south, central and east Europe has led some scientists to think that Europe may have once had literal herds of cave bears. Some however point out that though some caves have thousands of bones, they were accumulated over a period of 100,000 years or more, thus requiring only two deaths in a cave per year to account for the large numbers.

The cave bear inhabited low mountainous areas, especially in regions rich in limestone caves. They seem to have avoided open plains, preferring forested or forest-edged terrains.

Anatomy

Life restoration

The cave bear had a very broad, domed skull with a steep forehead. Its stout body had long thighs, massive shins and in-turning feet, making it similar in skeletal structure to the brown bear. Cave bears were comparable in size to the largest modern day bears. The average weight for males was 400-500 kilograms (880-1102 pounds), while females weighed 225–250 kg (496-551 lbs). Of cave bear skeletons in museums, 90% are male due to a misconception that the female skeletons were merely "dwarfs". Cave bears grew larger during glaciations and smaller during interglacials, probably to adjust heat loss rate. Cave bears of the last ice age lacked the usual 2-3 premolars present in other bears; to compensate, the last molar is very elongated, with supplementary cusps. The humerus of the cave bear was similar in size to that of the polar bear, as were the femora of females. The femora of male cave bears, however, bore more similarities in size to those of kodiak bears.

Dietary habits

Cave bear teeth show greater wear than most modern bear species, suggesting a diet of tough materials. However, tubers and other gritty food, which cause distinctive tooth wear in modern brown bears, do not appear to have constituted a major part of cave bears' diet on the basis of dental microwear analysis.

Skull of *Ursus spelaeus*. Cave bears lacked the usual 2-3 premolars present in other bear species

The morphological features of the cave bear chewing apparatus, including loss of premolars, have long been suggested to indicate that their diets displayed a higher degree of herbivory than the Eurasian brown bear. Indeed, a solely vegetarian diet has been inferred on the basis of tooth morphology. Results obtained on the stable isotopes of cave bear bones also point to a largely vegetarian diet in having low levels of nitrogen-15 and carbon-13, which are accumulated at a faster rate by meat eaters as opposed to herbivores.

However, some evidence points toward inclusion of at least occasional animal protein in the cave bear diet. For example, toothmarks on cave bear remains in areas where cave bears are the only recorded potential carnivores suggests occasional cannibalistic scavenging, possibly on individuals that died during hibernation, and dental microwear analysis indicates that the cave bear may have fed on a greater quantity of bone than its contemporary, the smaller Eurasian Brown Bear. Additionally, cave bear remains from Peştera cu Oase in the southwestern tip of the Carpathian mountains had elevated levels of nitrogen-15 in their bones, indicative of an omnivorous diet, although the values are within the range of those found for the strictly herbivorous mammoth.

Although the current prevailing opinion concludes that cave bears were largely herbivorous, and more so than any modern species of the genus *Ursus*, increasing evidence points to an omnivorous diet, based both on regional variability of isotopic composition of bone remains indicative of dietary plasticity, and on a recent reevaluation of its craniodental morphology that places the cave bear squarely among omnivorous modern bear species with respect to its skull and tooth shapes.

Mortality

Standing skeleton of juvenile cave bear

Death during hibernation was a common end for cave bears, mainly befalling specimens that failed ecologically during the summer season through inexperience, sickness or old age. Some cave bear bones show signs of numerous different ailments, including fusion of the spine, bone tumours, cavities, tooth resorption, necrosis (particularly in younger specimens), osteomyelitis, periostitis, rickets and kidney stones. Male cave bear skeletons have been found with broken baculums, probably due to fighting during breeding season. Cave bear longevity is unknown, though it has been estimated that they seldom exceeded 20 years of age. Paleontologists doubt adult cave bears had any natural predators, save for pack hunting wolves and cave hyenas which would probably have attacked sick or infirm specimens. Cave hyenas are thought to be responsible for the disarticulation and destruction of some cave bear skeletons. Such large carcasses were an optimal food resource for the hyenas, especially at the end of the winter, when food was scarce. The presence of fully articulated adult cave lion skeletons, deep in cave bear dens, indicates that lions may have occasionally entered dens to prey on hibernating cave bears, with some dying in the attempt.

Evolution

Skeleton mounted in quadrupedal posture

Both the cave bear and the brown bear are thought to be descended from the Plio-Pleistocene Etruscan bear (*Ursus etruscus*) that lived ~5.3 Mya to 10,000 years ago. The last common ancestor of cave bears and brown bears lived between 1.2 and 1.4 million years ago. The immediate precursor of the cave bear was probably *Ursus deningeri* (Deninger's bear), a species restricted to Pleistocene Europe ~1.8 Mya to 100,000 years ago. The transition between Deninger's bear and the cave bear is given as the last Interglacial, although the boundary between these forms is arbitrary and intermediate or transitional taxa have been proposed, e.g. *Ursus spelaeus deningeroides*, while other authorities consider both taxa to be chronological variants of the same species.

Cave bears found in different regions vary in age, thus facilitating investigations into evolutionary trends. The three anterior premolars were gradually reduced, then disappeared, possibly in response to a largely vegetarian diet. In a fourth of the skulls found in the Conturines, the third premolar is still present, while more derived specimens elsewhere lack it. The last remaining premolar became conjugated with the true molars, enlarging the crown and granting it more cusps and cutting borders. This phenomenon known as molarization improved the mastication capacities of the molars, facilitating the processing of tough vegetation. This allowed the cave bear to gain more energy for hibernation while eating less than its ancestors.

Recovery of fossil DNA

In May 2005, scientists in California succeeded in recovering and sequencing nuclear DNA of a cave bear that lived between 42,000 and 44,000 years ago. The procedure used genomic DNA extracted from the animal's tooth. Sequencing the DNA directly (rather than first replicating it with the polymerase chain reaction), the scientists were able to recover 21 cave bear genes from remains that did not yield significant amounts of DNA with traditional techniques. This study confirmed and built on results from a previous study using mitochondrial DNA extracted from cave bear remains ranging from 20,000 to 130,000 years old. Both show the cave bear to be more closely related to the brown bear and polar bear than the American black bear, but having split from the brown bear lineage prior to the diversification of distinct eastern and western brown bear lineages and prior to the split of brown bears and polar bears. The divergence date estimate of cave bears and brown bears is ~1.2-1.4 Mya.

Causes of extinction

Recent reassessment of fossils indicate the cave bear probably died out 27,800 years ago. It has been suggested that a complex of factors, rather than a single factor, led to the extinction.

Compared with other megafaunal species that also became extinct during the last Glacial Maximum, the cave bear was believed to have had a more specialized diet of high-quality plants and a relatively restricted geographical range. This was suggested as an explanation as to why it died out so much earlier than the rest. Some experts have disputed this claim as the cave bear had survived multiple climate changes prior to extinction. Additionally, mitochondrial DNA research indicated that the genetic decline of the cave bear began long before it went extinct, demonstrating that habitat loss due to climate change was not responsible. Finally, high $\delta^{15}N$ levels were found in cave bear bones from Romania, indicating wider dietary possibilities than previously believed.

Overhunting by humans has been largely dismissed because human populations at the time were too small to pose a serious threat to the cave bear's survival, though there is evidence that the two species may have competed for living space in caves. Unlike brown bears, cave bears are seldom represented in cave paintings, leading some experts to believe that the cave bear may have been avoided by human hunters or their habitat preferences may not have overlapped. One theory proposed by late paleontologist Bjorn Kurten states that the cave bear populations were fragmented and under stress even before the advent of the glaciers. It is possible that populations living south of the Alps survived significantly longer.

There is some evidence that the cave bear only used caves for hibernation and was not inclined to use other locations, such as thickets, for this purpose, in contrast to the more versatile Brown Bear. This specialized hibernation behavior would have caused a high winter mortality rate for Cave Bears that failed to find available caves. Therefore, as human populations slowly increased, the Cave Bear faced a shrinking pool of suitable caves, and slowly faded away to extinction, as both Neanderthals and anatomically modern humans sought out caves as living quarters, depriving the cave bear of vital habitat. This hypothesis is being researched at this time.

Cave bear worship

Collections of bear bones at several widely dispersed sites suggest that Neanderthals may have worshipped cave bears, especially at Drachenloch, in Switzerland, where a stone chest was discovered with a number of bear skulls stacked upon it. Neanderthals, who also inhabited the entrance of the cave, are believed to have built it. A massive stone slab covered the top of the structure. At the cave entrance, seven bear skulls were arranged with their muzzles facing the cave entrance, while deeper in the cave, a further six bear skulls were lodged in niches along the wall. Next to these remains were bundles of limb bones belonging to different bears. Consequently, it was at this site that the supposed symbol of the "Cult of the Cave Bear" was found. This consisted of the skull of a three-year-old bear pierced in the cheek by the leg-bone of younger bear. The arrangement of these bones of different bears are not believed to have happened by chance.

A similar phenomenon was encountered in Regourdou, southern France. A rectangular pit contained the remains of at least twenty bears, covered by a massive stone slab. The remains of a Neanderthal lay nearby in another stone pit, with various objects, including a bear humerus, a scraper, a core, and some flakes, which were interpreted as grave offerings.

The unusual finding in a deep chamber of Basua Cave in Savona, Italy, is thought to be related to cave bear worship, as there is a vaguely zoomorphic stalagmite surrounded by clay pellets. It was apparently used by Neanderthals for a ceremony; the fact that bear bones lay scattered on the floor further suggests that this was likely to have had some sort of ritual purpose.

Chapter- 8

Cave Hyena

The **Cave Hyena** (*Crocuta crocuta spelaea*) is an extinct subspecies of spotted hyena (*Crocuta crocuta*) native to Eurasia, ranging from Northern China to Spain and into the British Isles. Though originally described as a separate species from the spotted hyena due to large differences in fore and hind extremities, genetic analysis indicates no sizeable differences in DNA between Pleistocene cave hyena and modern day spotted hyena populations. It is known from a range of fossils and prehistoric cave art. With the decline of grasslands 12,500 years ago, Europe experienced a massive loss of lowland habitats favoured by cave hyenas, and a corresponding increase in mixed woodlands. Cave hyenas, under these circumstances, would have been outcompeted by wolves and humans which were as much at home in forests as in open lands, and in highlands as in lowlands. Cave hyena populations began to shrink after roughly 20,000 years ago, completely disappearing from Western Europe between 14-11,000 years ago, and earlier in some areas.

Description

The main distinction between the spotted hyena and the cave hyena is grounded on different lengths of the hind and fore limb bones. The humerus and femur are longer in the cave hyena, indicating an adaptation to a different habitat to that of the spotted hyena. It is unknown if they showed the same sexual dimorphism of the spotted hyena. It has been estimated that they weighed 102 kg (225 lbs).

Little is known of their social habits. It is widely accepted that they used caves as dens, although sites in the open-air are also known. There is no indication of cave hyenas living in large clans or on a more solitary basis, though large clans are not considered likely in their Pleistocene habitat.

Dietary habits

Reconstruction of cave hyena

Like modern hyenas, cave hyenas accumulated the bones and horns of their food at den sites for later consumption or for play, though it is unknown if the discovered remains were from scavenged or killed animals. Studies of animal remains in hyena den sites in the Bohemian Karst show that Przewalski's Horses were apparently their most common prey, which amounted to 16-51% of the cave hyena's prey. Their largest prey was the woolly rhinoceros, the bones and skulls of which have been found in many hyena den sites. In some regions, rhino remains can comprise 25-30% of the total prey bone material in den sites. Reindeer were another important food source, as they made up 7-15% of the cave hyena's prey. The Steppe Wisent made up only 1-6% of the cave hyena's prey. Red deer only comprised 3% of found remains, with Irish elk being even rarer. The remains of alpine fauna including chamois and ibex are absent in some places, representing less than 3% of the prey, possibly due to their greater fragility. There is evidence that cave hyenas occasionally practiced cannibalism.

Interspecific predatory relationships

Cave hyenas were highly successful predators, and were especially numerous in Northeast Asia, where it seems they outcompeted most other predators. This was deduced from the relative scarcity of cave lion, cave bear and wolf remains in areas where they are sympatric with hyenas.

Cave hyenas are thought to be responsible for the dis-articulation and destruction of some cave bear skeletons. Such large carcasses were an optimal food resource for the hyenas, especially at the end of the winter, when food was scarce.

Cave hyenas were sympatric with gray wolves in Italy. Unlike the hyenas, which preferentially preyed on lowland animals such as horses, wolves relied more on smaller, slope-dwelling prey such as ibex and roe deer, thus minimizing competition. Wolves and cave hyenas seem to display negative abundance relations over time, with wolf populations expanding their ranges as hyenas disappeared.

Interactions with hominids

Cave hyena painting found in the Chauvet Cave in 1994.

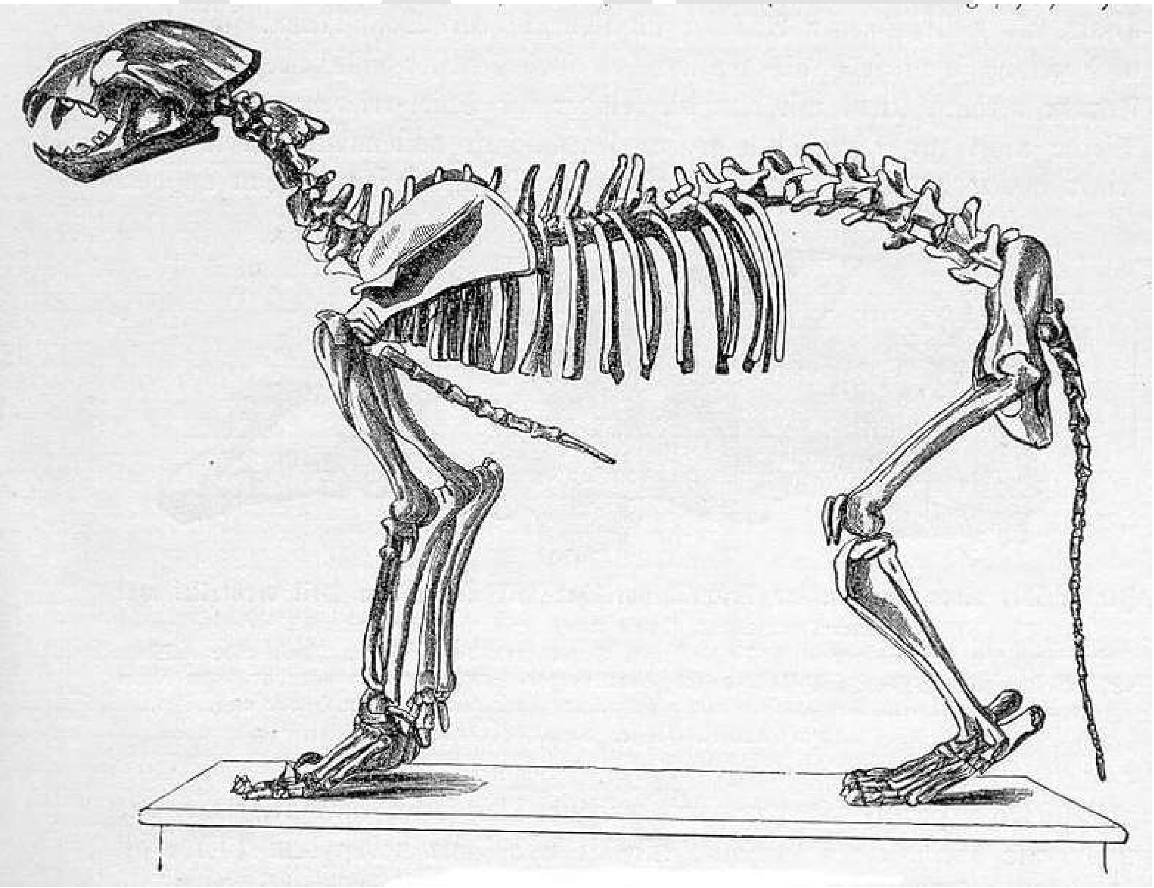
Kills partially processed by Neanderthal and then by cave hyena indicate that hyena would occasionally steal Neanderthal kills, and cave hyena and Neanderthal both competed for cave sites. Many caves show alternating occupations of hyenas and Neanderthals. Numerous hominid bones, including Neanderthal, have also been found partially consumed by cave hyena. Modern humans also lived alongside cave hyena, and may have had similar interaction with them. Some paleontologists believe that competition and predation by cave hyenas in Siberia was a significant factor in delaying human colonization of Alaska. Cave hyenas may have occasionally stolen human kills, or entered campsites to drag off the young and weak, much like modern spotted hyenas in Africa. The oldest Alaskan human remains coincide with roughly the same time cave hyenas became extinct, leading certain paleontologists to infer that hyena predation was what prevented humans from crossing the Bering strait earlier.

Chapter- 9

Panthera Leo Spelaea

Panthera leo spelaea also known as the **European** or **Eurasian cave lion**, is an extinct subspecies of lion known from fossils and many examples of prehistoric art.

Physical characteristics



Skeleton of a cave lion from the Sloup Caves near Brno in the Czech Republic

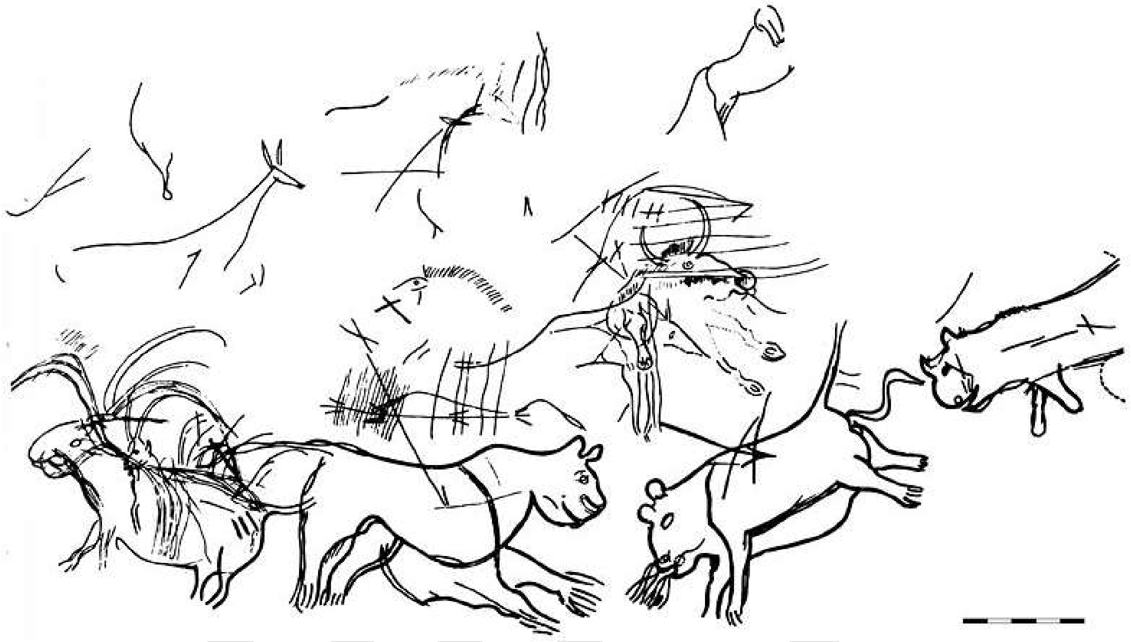
This subspecies was one of the largest lions. The skeleton of an adult male, which was found in 1985 near Siegsdorf (Germany), had a shoulder height of around 1.2 m (4 ft) and a body length of 2.1 m (7 ft) without tail. This is similar to the size of a very large modern lion. The size of this male has been exceeded by other specimens of this subspecies. Therefore this cat may have been around 8%-10% bigger than modern lions, but it surpassed the reach of measures of the earlier cave lion subspecies *Panthera leo fossilis* or those of the huge American lion (*Panthera leo atrox*). The cave lion is known from Paleolithic cave paintings, ivory carvings, and clay figurines. These representations indicate that cave lions had rounded, protruding ears, tufted tails, possibly faint tiger-like stripes, and that at least some had a "ruff" or primitive mane around their neck, indicating males. Other archaeological artifacts indicate that they were featured in Paleolithic religious rituals.

Environment

Restoration by Heinrich Harder

The cave lion received its common name because large quantities of its remains are found in caves , but it is doubtful whether they lived in them. It had a wide habitat tolerance, but probably preferred conifer forests and grasslands , where medium-sized to large herbivores occurred. Fossil footprints of lions, which were found together with those of reindeer, demonstrate that lions once occurred even in subpolar climates. The presence of fully articulated adult cave lion skeletons, deep in cave bear dens, indicates that lions may have occasionally entered dens to prey on hibernating cave bears, with some dying in the attempt.

These active carnivores probably preyed upon the large herbivorous animals of their time, including horses, deer and bison. Some paintings of them in caves show several hunting together, which suggests the hunting strategy of contemporary lionesses.



Cave lions, *Chamber of Felines*, Lascaux caves in France

Small prey was usually brought down with a blow of the front paw and then held down with both front feet. The animal was finally killed by a powerful bite of the sharp teeth , at the back of the neck, in the region of the throat and even in the chest. A cave lion usually could not run as fast as its prey, but could pounce on it from behind or run up next to it and bring it down with the paws. In this manner a running animal's balance could very easily be disturbed.

It was most likely the most common predator (after the cave hyena) in plains ecosystems. Its extinction may have been related to the Quaternary extinction event, which wiped out most of the megafauna prey in those regions. Cave paintings and remains found in the refuse piles of ancient camp sites indicate that they were hunted by early humans, which also may have contributed to their demise.

Classification

The cave lion is sometimes considered a species in its own right, under the name *Panthera spelaea* , and at least one authority, based on a comparison of skull shapes, considers the cave lion to be more closely related to the tiger, which would result in the formal name *Panthera tigris spelaea*. However, recent genetic research shows that it was a close relative of the modern lion and that it formed a single population with the Beringian cave lion, which has been sometimes considered as to represent a distinct form.

Therefore the cave lion ranged from Europe to Alaska over the Bering land bridge until the latest Pleistocene. However it is still not completely clear, whether it was a subspecies of the lion or rather a very close relative

History and distribution

Cave lions with a reindeer (artist's impression).

The cave lion (*Panthera leo spelea*) was derived from the earlier *Panthera leo fossilis*, which first appeared in Europe about 700,000 years ago. The cave lion itself lived from 370,000 to 10,000 years ago, during the Pleistocene epoch. Apparently, it became extinct about 12,500 C-14 years ago , during the Würm glaciation, although there are some indications it may have existed into historic times in southeastern Europe, as recently as 2,000 years ago in the Balkans.

Cave lions were widespread in parts of Europe and Asia, from Great Britain, Germany and Spain (Arduini & Teruzzi, 1993) all the way to the Bering Strait and from Siberia to Turkistan.

Chapter- 10

Dwarf Elephant

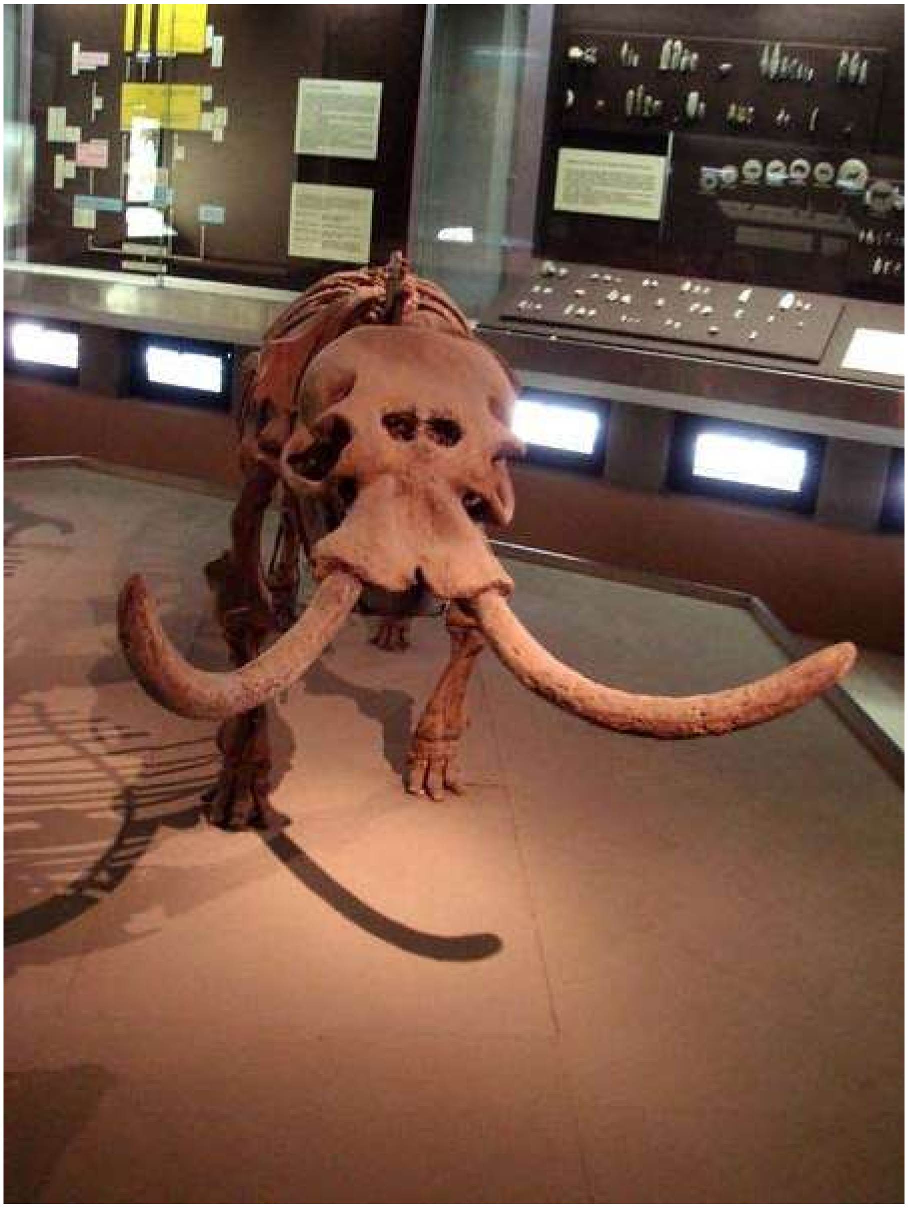
Dwarf elephants are prehistoric members of the order Proboscidea, that, through the process of allopatric speciation, evolved to a fraction of the size of their immediate ancestors. Insular dwarfism is a biological phenomenon by which the size of animals isolated on an island shrinks dramatically over time for the smaller animals have survived because of the underabundance of food.

Fossil remains of dwarf elephants have been found on the Mediterranean islands of Cyprus, Malta (at Ghar Dalam), Crete, Sicily, Sardinia, the Cyclades Islands and the

Dodecanese Islands. Other islands where dwarf elephants have been found are Sulawesi, Flores, Timor and other islands of the Lesser Sundas. The Channel Islands of California once supported a dwarf species descended from Columbian mammoths, while small races of woolly mammoths were once found on Wrangel Island and Saint Paul Island.

Mediterranean Islands

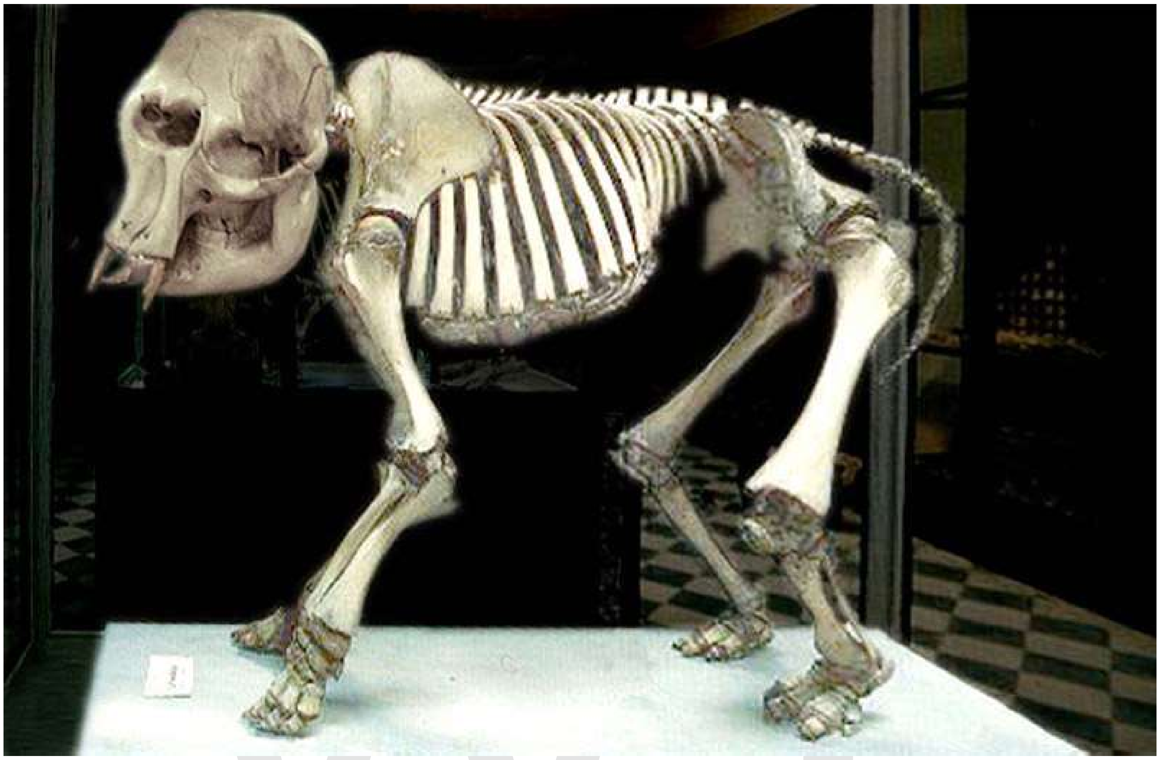
Dwarf elephants were, after the Messinian salinity crisis, part of the Pleistocene fauna of all the larger Mediterranean islands, with the apparent exception of Corsica and the Balearics. Mediterranean dwarf elephants have generally been considered as paleoloxodontine, derived from the continental Straight-tusked Elephant, *Elephas (Palaeoloxodon) antiquus* Falconer & Cautley, 1847. An exception is the dwarf Sardinian Mammoth, *Mammuthus lamarmorae* (Major, 1883), the only endemic elephant of the Mediterranean islands belonging to the mammoth line. A DNA research published in 2006 theorized that the *Elephas creticus* could be from the mammoth line too. This old theory, proposed by Dorothea Bate as early as 1905, is not widely accepted. A scientific study of 2007 demonstrates the mistakes of the DNA research of 2006.



Elephas Falconeri

During low sea levels, the Mediterranean islands were colonised again and again, giving rise, sometimes on the same island, to several species (or subspecies) of different body sizes. These endemic dwarf elephants were taxonomically different on each island or group of very close islands, like the Cyclades archipelago.

There are many uncertainties about the time of colonisation, the phylogenetic relationships and the taxonomic status of dwarf elephants on the Mediterranean islands. Extinction of the insular dwarf elephants has not been correlated with the arrival in the islands of man. Furthermore, it has been suggested by the paleontologist Othenio Abel in 1914, that the finding of skeletons of such elephants sparked the idea that they belonged to giant cyclopses, because the center nasal opening was thought to be a cyclopic eye socket.



Dwarf elephant skeleton of Malta

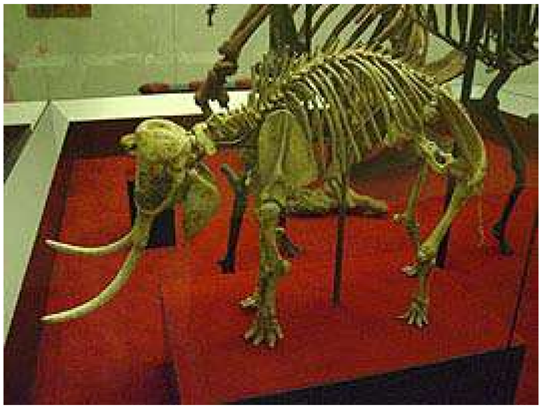
Sardinia

- *Mammuthus lamarmorae* (Major, 1883)
- *Elephas (Palaeoloxodon) antiquus* (Acconci, 1881)
- *Elephas (Palaeoloxodon) melitensis* Falconer, 1868

Sicily & Malta

- *Elephas (Palaeoloxodon) antiquus leonardii* Aguirre, 1969
- *Elephas (Palaeoloxodon) mnaidriensis* (Adams, 1874)
- *Elephas (Palaeoloxodon) melitensis* Falconer, 1868
- *Elephas (Palaeoloxodon) falconeri* Busk, 1867

Crete



Skeleton of a Cretan Dwarf Elephant.

- *Elephas (Palaeoloxodon) creticus* (Bate, 1907)
- *Elephas (Palaeoloxodon) creutzburgi* (Kuss, 1965)
- *Elephas (Palaeoloxodon) chaniensis* (Symeonides et al., 2001)

After DNA research, published in 2006, it has been proposed to rename *Elephas (Palaeoloxodon) creticus* into *Mammuthus creticus* (Bate, 1907). Others proposed (in 2002) to rename all the described specimens of larger size under the new subspecies name *Elephas antiquus creutzburgi* (Kuss, 1965). In a recent study of 2007, it was argued for the groundlessness of the theory by Poulakakis et al. in 2006, showing the weak points of that DNA research.

Cyprus

- *Elephas (Palaeoloxodon) cypriotes* Bate, 1903

The Cyprus dwarf elephant survived at least until 11,000 BP. Its estimated body weight was only 200 kg, only 2% of its 10,000 kg ancestor. Molars of this dwarf are reduced to approximately 40% the size of mainland straight-tusked elephants.

Remains of the species were first discovered and recorded by Dorothea Bate in a cave in the Kyrenia hills of Cyprus in 1902 and reported in 1903.

Cyclades Islands

Remains of paleoloxodontine elephants have been reported from the islands of Delos, Naxos, Kythnos, Serifos and Milos. The Delos elephant is of similar size to a small *Elephas antiquus*, while the Naxos elephant is of similar size to *Elephas melitensis*. The remains from Kythnos, Serifos and Milos have not been described.

Dodecanese Islands

On the island of Rhodes, bones of an endemic dwarf elephant have been discovered. This elephant was similar in size to *Elephas mnaidriensis*.

Two groups of remains of dwarf elephants have been found on the island of Tilos. They are similar in size to *Elephas mnaidriensis* and the smaller *Elephas falconeri*, but the two groups indicate sexual dimorphism. The remains had originally been designated to *Palaeoloxodon antiquus falconeri* (Busk, 1867). However, this name refers to the dwarf elephants from the island of Malta. As a result, since no migration route between the two islands can be proved, this name should not be used when referring to the elephant remnants from Tilos, although some scientists have accepted the temporary use of this name until further material can be examined.

The Tilos dwarf elephant is the first dwarf elephant whose DNA sequence has been studied. The results of this research are consistent with previous morphological reports, according to which *Palaeoloxodon* is more closely related to *Elephas* than to *Loxodonta* or *Mammuthus*. After the study of new osteological material <Theodorou et al. 2007> that has been excavated in anatomical connection in the Charkadio Cave on Tilos island the new species name *Elephas tiliensis* has been assigned to the Tilos dwarf elephants. It was the latest paleoloxodontine to survive in Europe. They became extinct just less than 4,000 years BP, so this elephant survived well into the Holocene.

Channel Islands of California

The Columbian mammoth (*Mammuthus columbii*) produced a separate, isolated population at the end of the Pleistocene. One of these isolated groups was formed on the Channel Islands of California, most likely about 40,000 years ago (although the time of isolation is not fully known). Selective forces on the Channel Islands resulted in smaller animals, forming a new species, the Pygmy Mammoth *Mammuthus exilis*. Channel Islands mammoths ranged from 150–190 cm in shoulder height.

Wrangel Island

During the last ice age, woolly mammoths (*Mammuthus primigenius*) lived on Wrangel Island in the Arctic Ocean. It has been shown that mammoths survived on Wrangel Island until 1700 BCE, the most recent survival of any known mammoth population. They also survived on Saint Paul Island in the Bering Sea until 6000 BCE. Wrangel Island is thought to have become separated from the mainland by 12,000 years BP. Survival of a mammoth population may be explained by local geographic, topographic and climatic features, which entailed preservation of communities of steppe plants, as well as a degree of isolation sufficient to delay colonization by humans. St. Paul Island shares this characteristic of geographic isolation, implying that human hunting played a role in the disappearance of the woolly mammoth. Wrangel Island mammoths ranged from 180–230 cm in shoulder height and were for a time considered "dwarf mammoths". However this classification has been re-evaluated and since the Second International Mammoth Conference in 1999, these mammoths are no longer considered to be true "dwarf mammoths".

Indonesia

On Sulawesi and Flores evidence of a succession of distinct endemic island faunas has been found, including dwarfed elephants, dating until the Middle Pleistocene. Around the early Middle Pleistocene these dwarfed elephants were replaced by new immigrants of larger to intermediate sizes.

Flores

The present understanding of the succession of *Stegodon* species on Flores is that endemic dwarfs, represented by the Early Pleistocene species *Stegodon sondaarii*, became extinct around 840,000 years ago. These dwarf forms were then replaced by the medium to large-sized *Stegodon florensis*, a species closely related to the *Stegodon trigonocephalus* group found both in Java and in the islands of biogeographical Wallacea, separated by deep water from the Asian and Australian continental shelves. This Stegodon species went extinct about 12,000 years ago, presumably because of a volcanic eruption.

Sulawesi

The dwarfed *Stegodon sompoensis* lived during the Pleistocene on the island of Sulawesi. They had a shoulder height of only 1.5m.

Chapter- 11

Cooksonia

Cooksonia is an extinct grouping of primitive land plants. The earliest *Cooksonia* date from the middle Silurian, about 425 million years ago; the group continues to be an important component of the flora until the early Devonian. For historical reasons, while *Cooksonia* fossils are distributed globally, most type specimens come from Britain.

Morphology

Only the sporophyte phase of *Cooksonia* is currently known. Individuals were small, a few centimetres tall, and had a simple structure; they lacked leaves, flowers and roots — although it has been speculated that they grew from an unpreserved rhizome. They had a simple stalk, that branched dichotomously a few times. Each branch ended in a sporangium, a rounded, spore-bearing structure. Specimens of one species of *Cooksonia* have a dark stripe in the centre of their stalks, which has been interpreted as the earliest remains of water carrying tissue. Other *Cooksonia* species lacked such conducting tissue.

Cooksonia specimens occur in a range of sizes, and varied in width from ~0.03 to 3 mm. Specimens of different sizes were probably different species, not fragments of larger organisms: fossils occur in consistent size groupings, and sporangia and spore details are different in organisms of different sizes. The organisms probably exhibited determinate growth.

Some *Cooksonia* species can be shown to bear stomata, which had a role in gas exchange; this was probably to assist in transpiration-driven transport of solutes in the xylem, rather than primarily in photosynthesis, as suggested by their concentration at the tips of the axes. These clusterings of stomata are typically associated with a bulging in the axis at the neck of the sporangium, which may have contained photosynthetic tissue, reminiscent of some mosses.

Physiology

While reconstructions traditionally depict *Cooksonia* as a green and red, photosynthesising, self-sufficient stem, it is likely that the fossils instead preserve a sporophyte generation which was dependent on a gametophyte for its nutrition – a relationship that occurs in modern mosses and liverworts.

However, no fossil evidence of a gametophyte of *Cooksonia* has been discovered to date. Study of smaller *Cooksonia* fossils showed that once the tissue required to support the axes, protect them from desiccation, and transport water had been accounted for, no room remained for photosynthetic tissue. Further, the axis thickness is what would be expected if their sole role was to support the sporangium on their ends. It appears that, originally at least, the role of the axes was solely to ensure continued spore dispersal, even if the axis desiccated.

The widths of *Cooksonia* fossils span an order of magnitude; while the smaller ones could not possibly be self-sufficient, the larger axes could; this provides a possible illustration of the evolution of an independent sporophyte generation.

Taxonomy

The relationships between the known species of *Cooksonia* and modern plants remain unclear. They appear to represent plants that are near to the branching between Rhyniophyta and to the club mosses. It is considered likely that *Cooksonia* is not a clade, but rather represents a evolutionary grade or form genus. Indeed, four different forms of spore, probably representing four different species, have been found in sporangia identified as *C. pertoni*.

Specimens

The first *Cooksonia* species were described by William Henry Lang in 1937 and named in honor of Isabel Cookson, with whom he had collaborated, and who collected the type specimens of *Cooksonia pertoni* in Perton Quarry in 1934.

Five species of *Cooksonia* have been clearly identified. *C. pertoni*, *C. hemisphaerica*, *C. cambrensis*, *C. caledonica* and *C. paranensis*. They are distinguished primarily by the shape of the sporangia.

Chapter- 12

Sigillaria

Sigillaria
Fossil range: Carboniferous to Permian

Sigillaria root (*Stigmaria*) from the Llewellyn Formation.

Scientific classification

Kingdom:	Plantae
Division:	Lycopodiophyta
Class:	Isoetopsida
Order:	Lepidodendrales
Family:	Lepidodendraceae
Genus:	***Sigillaria***

Sigillaria is a genus of extinct, spore-bearing, arborescent (tree-like) plants which flourished in the Late Carboniferous period but dwindled to extinction in the early Permian period. It was a lycopodiophyte, and is related to the lycopsids, or club-mosses, but even more closely to quillworts, as was its associate *Lepidodendron*. *Sigillaria* was a tree-like plant, with a tall, occasionally forked trunk that lacked wood. Support came from a layer of closely packed leaf bases just below the surface of the trunk, while the center was filled with pith. The old leaf bases expanded as the trunk grew in width, and left a diamond-shaped pattern, which is evident in fossils. The trunk had photosynthetic tissue on the surface, meaning that it was probably green.

Sigillaria on display at State Museum of Pennsylvania, from Sharon, Mercer County, Pennsylvania

Sigillaria (bark) on display at State Museum of Pennsylvania, from Scranton, Lackawanna County, Pennsylvania

Replica of *Sigillaria* sp. in a laboratory of practices of the Faculty of Sciences of the University of A Coruña

The trunk was topped with a plume of long, grass-like, microphyllous leaves, so that the plant looked somewhat like a tall, forked bottlebrush. The plant bore its spores (not seeds) in cone-like structures attached to the stem. *Sigillaria*, like many ancient lycopods, had a relatively short life cycle - growing rapidly and reaching maturity in a few years.

Some have suggested that *Sigillaria* was monocarpic, meaning that it died after reproduction, though this is not proven. It was associated with *Lepidodendron*, the scale tree, in the Carboniferous coal swamps.

Chapter- 13

Lepidodendron

Lepidodendron
Fossil range: Carboniferous

The strobilus of *Lepidodendron*

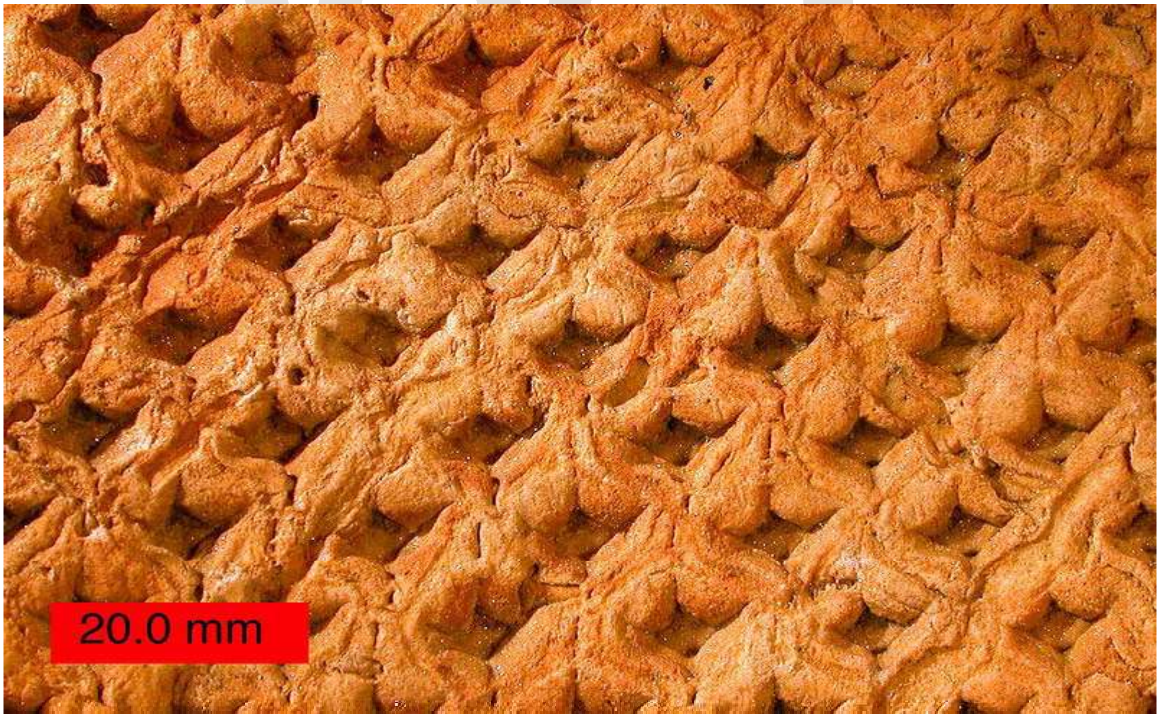
Scientific classification

Kingdom: Plantae
Division: Lycopodiophyta
Class: Isoetopsida
Order: Lepidodendrales
Family: Lepidodendraceae
Genus: ***Lepidodendron***

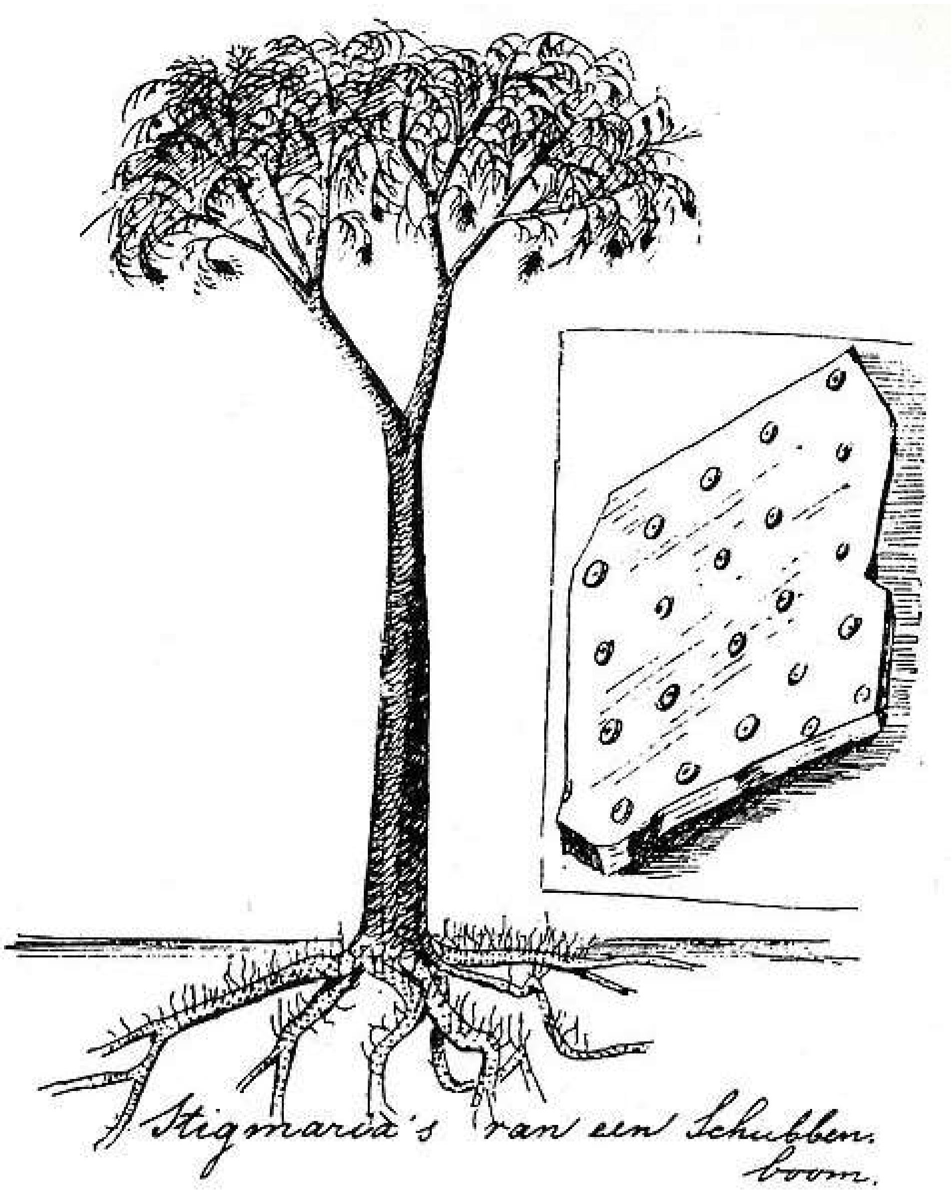
Lepidodendron (also known as the "Scale tree") is an extinct genus of primitive, vascular, arborescent (tree-like) plant related to the Lycopsids (club mosses). It was part of the coal forest flora. They sometimes reached heights of over 30 metres (100 ft), and the trunks were often over 1 m (3.3 ft) in diameter, and thrived during the Carboniferous period. Sometimes called "giant club mosses", this is actually not correct as they are actually closer to quillworts than to club mosses.

Lepidodendron had tall, thick trunks that rarely branched and were topped with a crown of bifurcating branches bearing clusters of leaves. These leaves were long and narrow, similar to large blades of grass, and were spirally-arranged. The vascular system was a siphonostele with exarch xylem maturation.

The closely packed diamond-shaped leaf scars left on the trunk and stems as the plant grew provide some of the most interesting and common fossils in Carboniferous shales and accompanying coal deposits. These fossils look much like tire tracks or alligator skin.



External mold of *Lepidodendron* from the Upper Carboniferous of Ohio.



Reconstruction of *Lepidodendron* by Dutch conservationist Eli Heimans (1911).

Lepidodendron on display at the State Museum of Pennsylvania

The scars, or leaf cushions, were composed of green photosynthetic tissue, evidenced by the cuticle covering and being dotted with stomata, microscopic pores through which carbon dioxide from the air diffuses into plants. Likewise, the trunks of *Lepidodendron* would have been green, unlike modern trees which have scaly, non-photosynthetic brown or gray bark.

Lepidodendron has been likened to a giant herb. The trunks produced very little, if any, wood. Most structural support came from a thick, bark-like region. This region remained around the trunk as a rigid layer that did not flake off like that of most modern trees. As the tree grew, the leaf cushions expanded to accommodate the increasing width of the trunk.

The branches of this plant ended in cone-like structures. *Lepidodendron* did not produce seeds like many modern plants. Instead, it reproduced by means of spores. It is estimated that these plants grew rapidly and lived 10–15 years. Some species were probably monocarpic, meaning they reproduced only once toward the end of their life cycle.

Lepidodendron likely lived in the wettest parts of the coal swamps that existed during the Carboniferous period. They grew in dense stands, likely having as many as 1000 to 2000 giant clubmosses per hectare. This would have been possible because they did not branch until fully grown, and would have spent much of their lives as unbranched poles. In its juvenile stages, the trunk was supported by grass-like leaves that grew straight out of the trunk.

By the Mesozoic era, the giant clubmosses had died out and were replaced by smaller clubmosses, probably due to competition from the emerging woody gymnosperms and other plants. *Lepidodendron* is one of the more common plant fossils found in Pennsylvanian (Late Carboniferous) age rocks. They are closely related to other extinct genera, *Sigillaria* and *Lepidendropsis*.

In the 19th Century, due to the reptilian look of the diamond-shaped leaf scar pattern, petrified trunks of *Lepidodendron* were exhibited at fairgrounds as giant fossil lizards or snakes.

The name *Lepidodendron* comes from the Greek *lepido*, scale, and *dendron*, tree.

Chapter- 14

Calamites

Calamites

Fossil range: Carboniferous–early Permian

A range of *Calamites* specimens, illustrating the different appearance of fossils preserved under different taphonomic modes.

Scientific classification

Kingdom:	Plantae
Division:	Pteridophyta
Class:	Equisetopsida
Order:	Equisetales
Family:	Calamitaceae
Genus:	***Calamites***

Calamites is a genus of extinct arborescent (tree-like) horsetails to which the modern horsetails (genus *Equisetum*) are closely related. Unlike their herbaceous modern cousins, these plants were medium-sized trees, growing to heights of more than 30 meters (100 feet). They were components of the understories of coal swamps of the Carboniferous period.

Taphonomy

A number of organ taxa have been identified as part of a united organism, which has inherited the name *Calamites* in popular culture. *Calamites* correctly refers only to casts of the stem of Carboniferous/Permian sphenophytes, and as such is a form genus of little taxonomic value. There are two forms of casts, which can give mistaken impressions of the organisms. The most common is an internal cast of the hollow (or pith-filled) void in the centre of the trunk. This can cause some confusion: firstly, it must be remembered that a fossil was probably surrounded with 4-5 times its width in (unpreserved) vascular tissue, so the organisms were much wider than the internal casts preserved. Further, the fossil gets narrower as it attaches to a rhizoid, a place where one would expect there to be the highest concentration of vascular tissue (as this is where the peak transport occurs). However, because the fossil is a cast, the narrowing in fact represents a constriction of the *cavity*, into which vascular tubes encroach as they widen.

Further organ genera belonging to sphenophytes include:

- *Arthropitys* (stems which are preserved in a mineralised form)
- *Astromyelon* (permineralised rhizomes, distinguished from *Arthropitys* by the absence of a carinal canal)
- *Annularia* and *Asterophylites* (form genera of leaf-whorls which are paraphyletic).

Anatomy

The foliage of *Calamites*

The trunks of *Calamites* had a distinctive segmented, bamboo-like appearance and vertical ribbing. The branches, leaves and cones were all borne in whorls. The leaves were needle-shaped, with up to 25 per whorl.

Their trunks produced secondary xylem, meaning they were made of wood. The vascular cambium of *Calamites* was *unifacial*, producing secondary xylem towards the stem center, but not secondary phloem.

The stems of modern horsetails are typically hollow or contain numerous elongated air-filled sacs. *Calamites* was similar in that its trunk and stems were hollow, like wooden tubes. When these trunks buckled and broke, they could fill with sediment. This is the reason pith casts of the inside of *Calamites* stems are so common as fossils.

Reproduction

A *Calamites* rhizoid

Calamites reproduced by means of spores, which were produced in small sacs organized into cones. They are also known to have possessed massive underground rhizomes, which allowed for the production of clones of one tree. This is the only group of trees of their period known to have a clonal habit. This type of asexual reproduction would allow them to spread quickly into new territory, and help to anchor them firmly in the unstable ground along rivers and in newly deposited delta sediments. The rhizomes of *Calamites* look quite similar to the stems in most cases, but have nodes that get progressively closer together as they approach the apical area (the growth tip that spreads outward through the soil).

Different forms

Calamites come in a variety of different "form genera". One type, *Calamites suckowi*, is distinguishable from other *Calamites* forms by its prominent, swollen nodes and relatively wide-spaced longitudinal ribs. Another example, *Calamites cisti*, has much smaller nodes and the ribs are typically closer together.

In addition, the distance between successive node lines on a *Calamites suckowi* specimen is typically much wider than the diameter. In other forms like *Calamites cisti*, the opposite is true or the specimen is just slightly wider than the diameter.

However, the value of these form taxa is limited. The distance between nodes, for example, is highly variable, and an intercalary meristem means that this distance varied as the organisms grew.

Extinction and classification

The genus *Calamites* has been placed in the plant division Equisetophyta (formerly known as Sphenophyta) and family Calamitaceae. They finally became extinct in the Lower Permian, a time which, however, also saw the origin of the family Equisetaceae, to which the only living sphenophyte genus *Equisetum* belongs.

Chapter- 15

Glossopteris

Glossopteris

Fossil range: Permian

Fossils of the gymnosperm *Glossopteris* (dark green) found in all of the southern continents provide strong evidence that the continents were once amalgamated into a supercontinent Gondwana

Scientific classification

Domain:	Eukaryota
(unranked):	Archaeplastida
Kingdom:	Plantae
Division:	†Pteridospermatophyta
Order:	Glossopteridales
Family:	Glossopteridaceae
Genus:	***Glossopteris*** Brongniart 1828 ex Brongniart 1831

Species

Glossopteris (Greek *glossa* (γλώσσα), meaning "tongue", because the leaves were tongue-shaped) is the largest and best-known genus of the extinct order of seed ferns known as Glossopteridales (or in some cases as Arberiales or Dictyopteridiales).

History

The Glossopteridales arose around the beginning of the Permian in the Southern Hemisphere. Their distribution across several, now detached, landmasses led Eduard Suess, amongst others, to propose that the southern continents were once amalgamated into a single supercontinent - Gondwana. These plants went on to become the dominant elements of the southern flora through the rest of the Permian but disappeared in almost all places at the end of the Permian. The only convincing Triassic records are very earliest Triassic leaves from Nidpur, India, but even these records are somewhat questionable owing to faulting and complex juxtapositioning of Permian and Triassic strata at Nidpur. Although most modern palaeobotany textbooks cite the continuation of glossopterids into later parts of the Triassic and, in some cases into the Jurassic, these ranges are erroneous and are based on misidentification of morphologically similar leaves such as *Gontriglossa*, *Sagenopteris*, or *Mexiglossa*. Glossopterids were, thus, one of the major casualties of the end-Permian mass-extinction event.

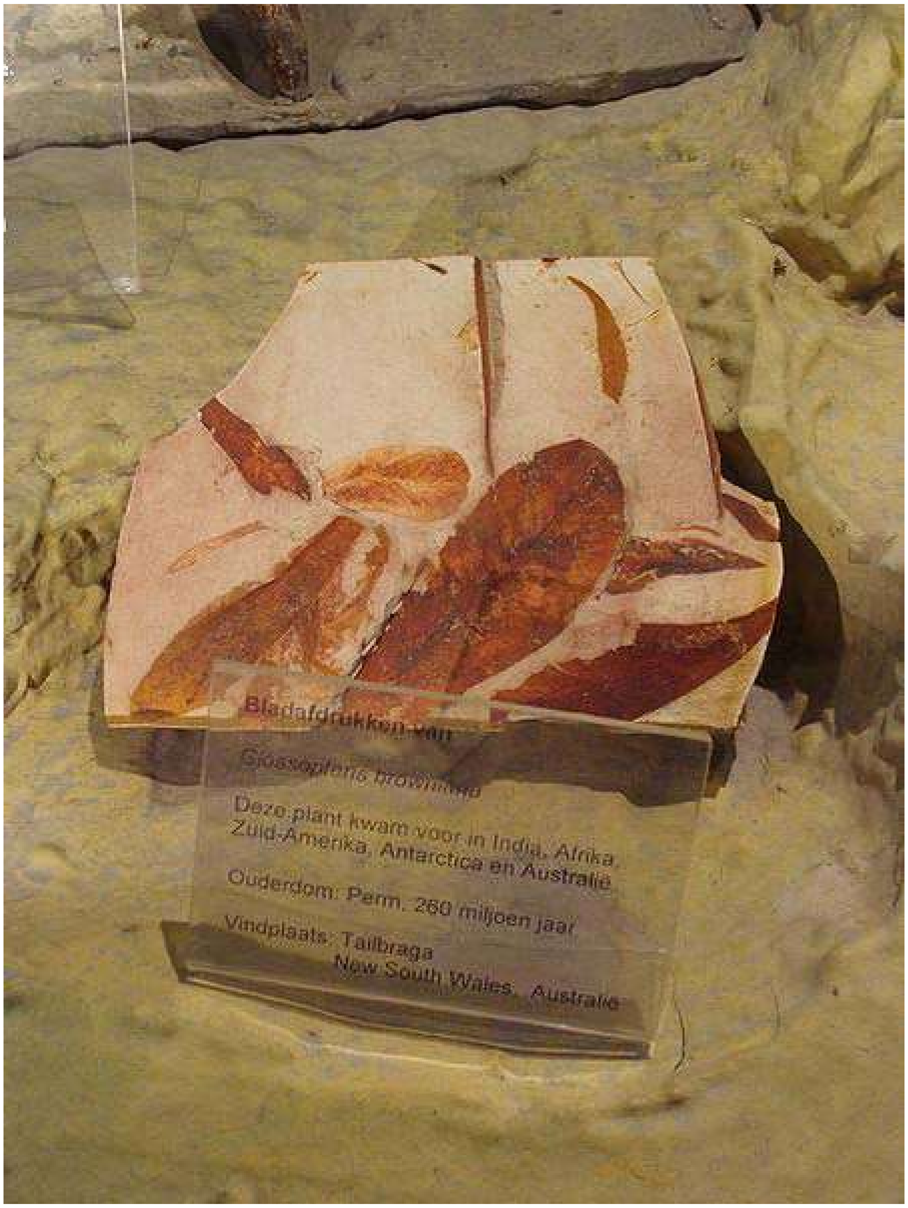
More than 70 fossil species of this genus have been recognized in India alone, with additional species from South America, Australia, Africa, Madagascar and Antarctica. Essentially, *Glossopteris* was restricted to the middle- and high-latitude parts of Gondwana during the Permian. Most northern parts of South America and Africa lack *Glossopteris* and its associated organs. However, in recent years a few disparate localities in Morocco, Oman, Anatolia, the western part of the island of New Guinea, Thailand and Laos have yielded fossils that are of possible glossopterid affinity. These peri-gondwanan records commonly occur together with Cathaysian or Euramerican plant species - the assemblages representing a zone of mixing between the strongly provincial floras of the Permian. Apart from those in India and the perigondwanan localities, a few other fossils from the Northern Hemisphere have been assigned to this group, but these are not identified with great certainty. For example, specimens assigned to *Glossopteris* from the far east of Russia in the 1960s are more likely to be misdentifications of other gymnosperms such as *Pursongia*. Confident assignment of fossil leaves to *Glossopteris* normally requires their co-preservation with the distinctive segmented roots of this group (called *Vertebraria*) or with the distinctive fertile organs.

Taxonomy

Long considered a fern after its discovery in 1824, it was later assigned to the gymnosperms. The genus is placed in the division Pteridospermatophyta. In reality, many of the plant groups included within this division are only distantly related to one another. Glossopterids' relationships with other groups remain obscure. Most recent phylogenetic analyses favour placement of glossopterids as sister to a large group including Corystospermales, Caytoniales, Bennettitales, Pentoxylales, Gnetales (in some analyses), and angiosperms. A few analyses favour alternative links with Ginkgoales, Cordaitales and Pinales.

Glossopteris should strictly be used to refer to the distinctive spathulate fossil leaves with reticulate venation, however, the term has also been used to refer to the parent plant as a whole.

Biology



Glossopteris browniana fossil in the Artis zoo, Amsterdam.

Glossopteris was a woody, seed-bearing shrub or tree, some apparently reaching 30 m tall. They had a softwood interior that resembles conifers of the family Araucariaceae. Seeds were borne on one side of variably branched or fused structures, and microsporangia containing pollen were borne in clusters at the tips of slender filaments.

Both the seed- and pollen-bearing organs were partially fused (adnate) to the leaves, or, in some cases, possibly positioned in the axils of leaves. The homologies of the flattened seed-bearing structures have remained particularly controversial with some arguing that the fertile organs represent megasporophylls (fertile leaves) whereas others have interpreted the structures as flattened, seed-bearing, axillary axes (cladodes). It is unclear whether glossopterids were monoecious or dioecious.

They are interpreted to have grown in very wet soil conditions, similar to the modern Bald Cypress. The leaves ranged from about 2 cm to over 30 cm in length.

The profile of glossopterid trees is largely speculative as complete trees have not been preserved. However, based on analogies with modern high-latitude plants *Glossopteris* trees probably tapered upwards like a Christmas tree and were relatively widely spaced to take advantage of the low-angle sunlight at high latitudes. Instead of needles, they had large, broad lance- or tongue-shaped leaves that fell to the ground at the end of summer. The fossil leaves are commonly found as dense accumulations representing autumnal leaf banks. The fossilized tree rings in the *Glossopteris* trees reveal that they grew steadily each spring-summer and abruptly stopped for winter.

Glossopteris leaves are morphologically simple so there are few characters that can be used to differentiate species. Consequently, many past researchers have considered the Permian *Glossopteris* flora to be rather homogeneous with the same species distributed throughout the Southern Hemisphere. However, more recent studies of the more morphologically diverse fertile organs have shown that taxa had more restricted regional distributions and several intra-gondwanan floristic provinces are recognizable. Nevertheless, several species of leaves found in Antarctica are common in the rocks of similar geologic age in India, located north of the equator and half a world away. Seeds, much too large to be wind-borne, could not have blown across thousands of miles of open sea, nor is it likely they have floated across vast oceans. Observations such as these led the Austrian geologist Eduard Suess to deduce that there had once been a land bridge between these areas. He named this large land mass Gondwanaland (named after the district in India where the plant *Glossopteris* was found). These same observations would also lend support to Alfred Wegener's Continental drift theory.

The first Antarctic specimens of *Glossopteris* were discovered by members of Scott's doomed Terra Nova Expedition. The expedition members abandoned much of their gear in an effort to reduce their load, but kept 35 pounds of *Glossopteris* fossils; these were found alongside their bodies.

Chapter- 16

Archaeamphora

Archaeamphora **Fossil range: Early Cretaceous**	

Artist's restoration of
Archaeamphora longicervia.

Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Eudicots
(unranked):	Asterids
Order:	Ericales
Family:	?Sarraceniaceae
Genus:	***Archaeamphora***
Species:	***A. longicervia***

Binomial name

Archaeamphora longicervia
Li (2005)

Archaeamphora longicervia is an extinct species of pitcher plant bearing close affinities to extant members of the family Sarraceniaceae. Fossil material assigned to this taxon originates from the Early Cretaceous Yixian Formation of northeastern China.

Archaeamphora longicervia is the earliest known carnivorous plant and represents the only fossil record of pitcher plants (with the possible exception of some palynomorphs of uncertain nepenthacean affinity). Furthermore, the monotypic *Archaeamphora* is one of the three oldest known genera of angiosperms (flowering plants). Li (2005) notes that "the existence of a so highly derived Angiosperm in the Early Cretaceous suggests that Angiosperms should have originated much earlier, maybe back to 280 mya as the molecular clock studies suggested".

Etymology

The generic name *Archaeamphora* is derived from the Greek: αρχαίος, archaios, combining form in Latin archae- and the Greek *amphoreus* (*pitcher*). The specific epithet *longicervia* is derived from the Latin *longus* (*long*) and *cervicarius* (*with a neck*). The latter refers to the characteristic constriction in the pitchers of this species.

Fossil material

All known fossil material of *A. longicervia* originates from the Jianshangou Formation in Beipiao, western Liaoning, China. These Early Cretaceous beds constitute the lower part of the Yixian Formation, which is dated at 124.6 million years old. Nine specimens of *A. longicervia* have been found, including holotype CBO0220 and paratype CBO0754.

Description

Archaeamphora longicervia was a herbaceous plant growing to around 50 mm (2 in) in height. The stem, at least 21 mm (.8 in) long and 1.2 mm (.04 in) wide, bore distinctive vertical ridges and grooves. Pitchers were ascidiate in form and 30 to 40 mm (1.2 to 1.6 in) long. Mature pitchers and underdeveloped pitchers or phyllodia-like leaves were arranged spirally around the stem. Pitchers consisted of a tubular base, expanded middle section, constriction around the mouth, and a vertical, spoon-shaped lid. A single wing ran down the adaxial side of each pitcher. Three to five parallel major veins were present on the pitchers, along with a few intercostal veins and numerous small veinlets.

Two unusual bag-like structures were present on each pitcher, one on either side of the central wing. Similar but semi-circular structures were found on the margin of the lid. These structures exhibited strong yellow-green intrinsic fluorescence when exposed to 500 nm wavelength light.

Tiny glands, approximately 4 µm in diameter, were found on the inner surface of the pitchers and partially embedded in the grooves along the veins. These also showed very strong golden-yellow fluorescence.

A single seed was found intimately associated with the fossil material of *A. longicervia* and is presumed to belong to the same species. It is winged and reticulate-tuberculate in morphology, closely resembling the seeds of Sarraceniaceae taxa. The seed is oval-shaped, covered with black-brown warts, and measures 0.9 mm by 1.25 mm (.03 in by .05 in).

Taxonomy

The fossil material of *A. longicervia* was subjected to chemical analysis for oleanane, considered a key marker differentiating angiosperms from gymnosperms. Oleanane was detected in the pitcher plant specimens, suggesting that they belong to the angiosperms.

Several morphological features of *A. longicervia* suggest a close relationship to Sarraceniaceae; both taxa exhibit one or two pitcher wings, a smooth peristome, and pitchers that extend vertically from the top of a short petiole.

Pitchers of *Sarracenia purpurea*

Li (2005) suggests that *A. longicervia* is morphologically similar to modern *Sarracenia purpurea*. It shares with this species the spiral arrangement of its pitchers and phyllodia-like tubular leaves with parallel major veins. *Archaeamphora longicervia* also shows close affinity to species of the genus *Heliamphora* in having pitchers with a long neck and upright lid. Of particular note is the similarity between the thick semi-circular structures on the lid of *A. longicervia* and the large nectar-secreting "spoon" present on the upper posterior portion of *Heliamphora exappendiculata* pitchers.

Li (2005) mentions the discovery of another type of pitcher plant from the same formation. This variety differs from the type material of *A. longicervia* in having pitchers that lack any constriction before the mouth, instead gradually expanding from the petiole into a hollow trumpet-like shape. He suggests that it "should be a different species" from *A. longicervia*. An intermediate form with a wider neck is also reported, suggesting that pitcher plants were already a diversified group in the Early Cretaceous.

Habitat

The area inhabited by *A. longicervia* is thought to have experienced significant climatic fluctuations during the Early Cretaceous, ranging from arid or semi-arid to more humid conditions. The substrate in the region was mostly composed of lacustrine sediments and volcanic rocks.

Chapter- 17

Silphium

Ancient silver coin from Cyrene depicting a stalk of Silphium.

Silphium (also known as ***silphion*** or ***laser***) was a plant of the genus *Ferula*. Generally considered to be an extinct "giant fennel" (although some claim that the plant is really *Ferula tingitana*), it once formed the crux of trade from the ancient city of Cyrene for its use as a rich seasoning and as a medicine. It was so critical to the Cyrenian economy that most of their coins bore a picture of the plant (*illustration, right*).

Silphium was an important species in prehistory, as evidenced by the Egyptians and Knossos Minoans developing a specific glyph to represent the Silphium plant.

The valuable product was the resin (***laser***, ***laserpicium***, or ***lasarpicium***) of the plant. It was harvested in a manner similar to asafoetida, a plant with similar enough qualities to silphium that Romans, including the geographer Strabo, used the same word to describe both.

Aside from its uses in Greco-Roman cooking (as in recipes by Apicius), many medical uses were ascribed to the plant. It was said that it could be used to treat cough, sore throat, fever, indigestion, aches and pains, warts, and all kinds of maladies. Chief among its medical uses, according to Pliny the Elder, was its role as an herbal contraceptive. Given that many species in the parsley family have estrogenic properties, and some (such as wild carrot) have been found to work as an abortifacient, it is quite possible that the plant was pharmacologically active in the prevention or termination of pregnancy.

Legend said that it was a gift from the god Apollo. It was used widely by most ancient Mediterranean cultures; the Romans considered it "worth its weight in denarii."

Extinction

The reason for silphium's extinction is not entirely known. The plant grew along a narrow coastal area, about 125 by 35 miles, in Cyrenaica (in present-day Libya). Much of the speculation about the cause of its extinction rests on a sudden demand for animals that grazed on the plant, for some supposed effect on the quality of the meat. Overgrazing combined with overharvesting may have led to its extinction. The climate of the maghreb has been drying over the millennia, and desertification may also have been a factor. Another theory is that when Roman provincial governors took over power from Greek colonists, they over-farmed silphium and rendered the soil unable to yield the type that was said to be of such medicinal value. Theophrastus reports that the type of ferula specifically referred to as "silphium" was odd in that it only grew in the wild, and could not be successfully grown as a crop in tilled soil. The validity of this report is questionable, however, as Theophrastus was merely passing on a report from another source. Pliny reported that the last known stalk of silphium found in Cyrenaica was given to the Emperor Nero "as a curiosity".

Silphium retained a ghostly literary half-life in lists of aromatics copied one from another, until it makes perhaps its last, spectral appearance in the list of spices that the Carolingian cook should have at hand— *Brevis pimentorum que in domo esse debeant* ("A short list of condiments that should be in the home") — by an author named Vinidarius, whose excerpts of *Apicius* survive in one eighth century uncial manuscript. Vinidarius' own dates may not be much earlier.

Connection with the heart symbol

Ancient silver coin from Cyrene depicting a seed/fruit of Silphium.

There has been some speculation about the connection between silphium and the traditional heart shape (♥). The symbol is remarkably similar to the Egyptian "heart soul" (*ib*). The sexual nature of that concept, combined with the widespread use of silphium in ancient Egypt for birth control, and the fact that silphium seeds were heart-shaped, leads to speculation that the character for *ib* may have been derived from the shape of the silphium seed.

Contemporaneous writings help tie silphium to sexuality and love, as laserpicium makes an appearance in a poem (Catullus 7) of Catullus to his lover Lesbia. As well as in Pausanias' *Description of Greece* in which he says "For it so happened that his maiden daughter was living in it. By the next day this maiden and all her girlish apparel had disappeared, and in the room were found images of the Dioscuri, a table, and silphium upon it."

Heraldry

Il silfio d'oro reciso di Cirenaica

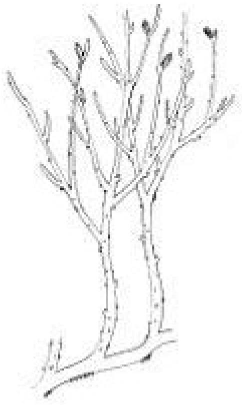
In the Italian military heraldry *Il silfio d’oro reciso di Cirenaica* (silphium *couped or* of Cyrenaica) was the symbol granted to the units that fought in the campaigns in North Africa during World War II.

Chapter- 18

Other Prehistoric Plants

Rhynia

Rhynia
Fossil range: Early Devonian



Reconstruction of *Rhynia gwynne-vaughanii*, redrawn after

Scientific classification

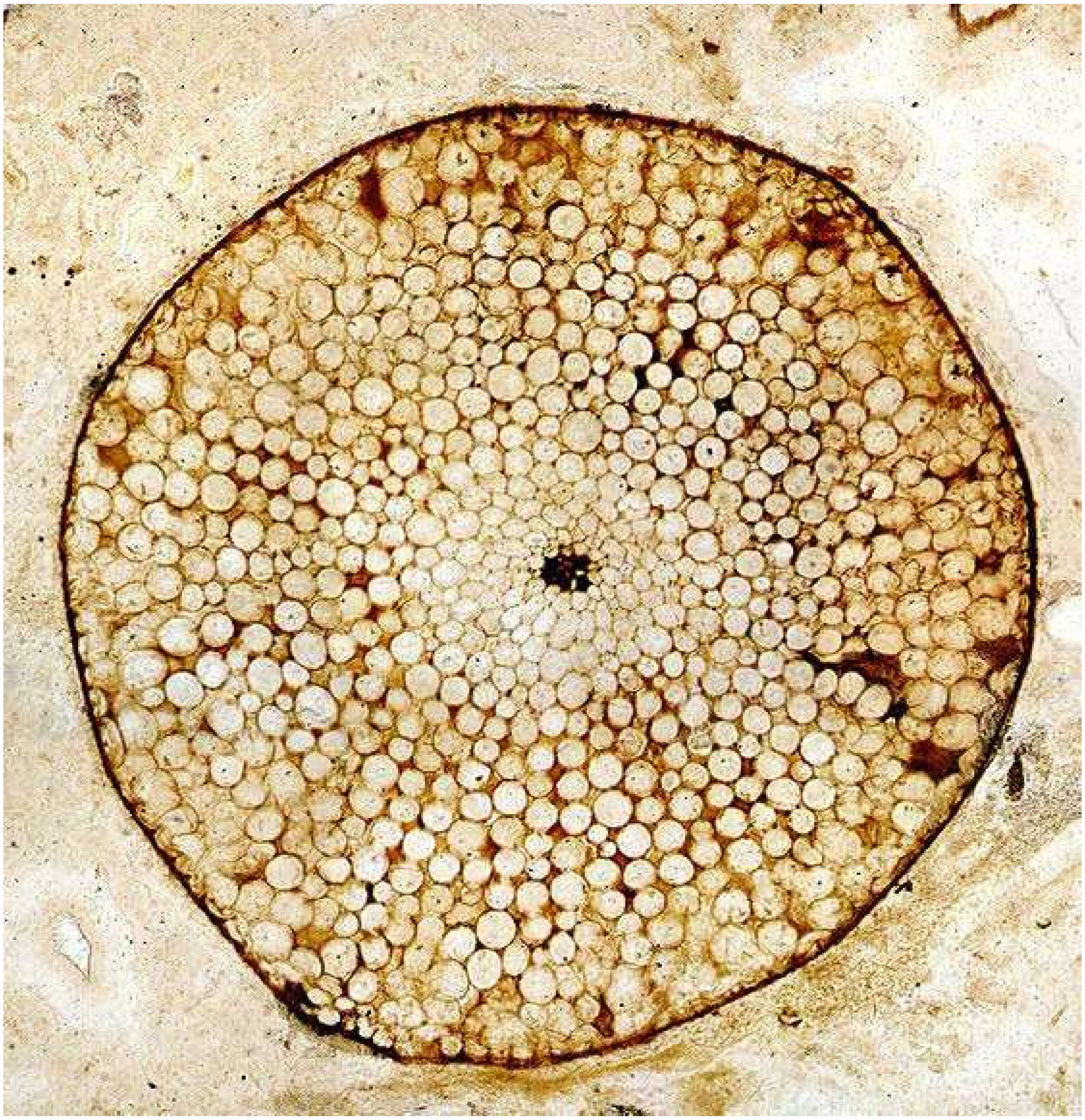
Kingdom:	Plantae
Division:	Rhyniophyta
Class:	Rhyniopsida
Order:	Rhyniales
Family:	Rhyniaceae
Genus:	***Rhynia*** Kidston & Lang (1917)
Species:	***R. gwynne-vaughanii***

Binomial name

Rhynia gwynne-vaughanii
Kidston & Lang (1917)

Rhynia gwynne-vaughanii was the sporophyte generation of a vascular, axial, free-sporing diplohaplontic embryophytic land plant of the Lower Devonian that had anatomical features more advanced than those of the bryophytes, and was basal to modern vascular plants or eutracheophytes.

R. gwynne-vaughanii was first described as a new species by Kidston and Lang in 1917. The species is known only from the Rhynie chert in Aberdeenshire, Scotland, where it grew in the vicinity of a silica-rich hot spring. *Rhynia* was a vascular plant, and grew in association with other vascular plants such as *Asteroxylon mackei*, a probable ancestor of modern clubmosses (Lycopsida), and with pre-vascular plants such as *Aglaophyton major*, which is interpreted as basal to true vascular plants.



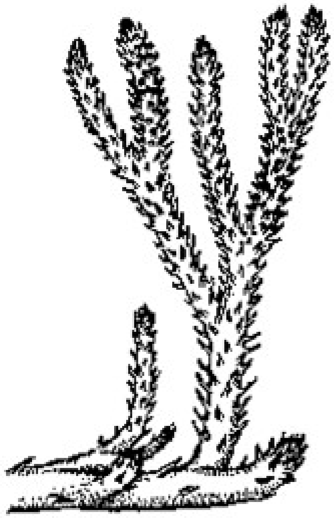
A transverse section of a stem of *Rhynia gwynne-vaughanii*, Lower Devonian, Rhynie chert

Rhynia is thought to have had deciduous lateral branches, which it used to disperse laterally over the substrate and stands of the plant may therefore have been clonal populations.

Evidence of the gametophyte generation of *Rhynia* has been described in the form of crowded tufts of diminutive stems only a few mm in height, with the form genus name *Remyophyton delicatum*. Like those of *Aglaophyton major*, *Horneophyton lignieri* and *Nothia aphylla* the gametophytes of *Rhynia* are dioicous, bearing male and female gametangia (antheridia and archegonia) on different axes. A significant finding is that the axes were vascular, unlike almost all of the gametophytes of modern pteridophytes except for that of Psilotum.

Drepanophycus

Drepanophycus
Fossil range: Devonian:
Lochkovian - Frasnian



Scientific classification

Kingdom:	Plantae
Division:	Lycopodiophyta
Class:	Lycopodiopsida
Order:	Drepanophycales
Family:	Drepanophycaceae
Genus:	***Drepanophycus*** Göppert, 1852

Species

- *Drepanophycus spinaeformis* Göppert (Type species)
- *Drepanophycus crepini*

(Gilkinet)

- *Drepanophycus qujingensis* Li & Edwards
- *Drepanophycus gaspianus* (Dawson) Kräusel & Weyland
- *Drepanophycus spinosus*

Another species has been described: *Drepanophycus colophyllus* Grierson & Banks - but this has since been removed to the genus *Haskinsia*.

Drepanophycus is a genus of extinct plants of the Division Lycopodiophyta of Early to Late Devonian age, found in Eastern Canada and Northeast USA, China, Russia, and various parts of Northern Europe and Britain.

Description

Extinct terrestrial vascular plants of the Devonian period. Stem of the order of several mm to several cm in diameter and several cm to a metre long, erect or arched, dichotomizing occasionally, furnished with true roots at the base. Vascular bundle actinostele, tracheids of primitive annular or helical type (so-called G-type). Leaves are unbranched thorn-shaped (i.e. with a wide base, tapering to a blunt point) microphylls several mm long with a single prominent vascular thread, arranged spirally to randomly on the stem. Sporangia borne singly on the upper leaf surface.

Drepanophycus differs from a closely related genus of the same period, Baragwanathia, in the position of the sporangia, and the arrangement and shape of the leaves.

It is more derived than the coexisting genus *Asteroxylon*, which has enations lacking vascules, in contrast to the true leaves of *Drepanophycus*.

Protosalvinia

Protosalvinia
Fossil range: Late Devonian

A fossil of *Protosalvinia furcata* from Devonian shale of Kentucky, USA.

Scientific classification

Kingdom:	Plantae
Phylum:	*incertae sedis*
Genus:	†***Protosalvinia***

Species

Protosalvinia arnoldii †
Protosalvinia braziliensis †
Protosalvinia furcata †
Protosalvinia ravenna †

Synonyms

Foerstia

Protosalvinia is a prehistoric plant found commonly in shale from shoreline habitats of the Upper Devonian period. The name *Protosalvinia* is a misnomer. The name literally means *early Salvinia*, and was given in the erroneous belief that the fossils were an earlier form of the living aquatic fern *Salvinia*. It is no longer believed that the fossils come from a fern, but deciding exactly what the fossils represent is still a matter of debate. This is surprising when one considers how much is known about the fossils.

The most likely interpretation of *Protosalvinia* is that it represents either a fossil liverwort or brown alga, although no definitive brown algae have been identified from before the Tertiary period, and examination of the spore structure shows no features in common with living groups of brown algae. The living plant was a thallus with short dichotomous branching. The branches in the largest species were as much as one centimeter across. In some fossils, the branching lobes lie flat, but in others the tips of the branches are curled up over the fossil, giving it a round outline. Embedded in the tissues of the thallus are chambers in which spores (200 micrometre diameter) were produced by meiosis.

Microscope slide mount of *Protosalvinia sp.* showing bifurcating thallus.

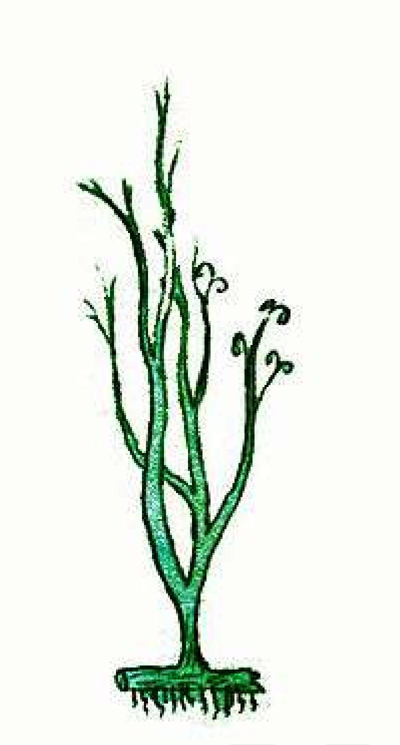
Because *Protosalvinia* is usually preserved as a compression fossil, it can be difficult to determine whether its anatomy is more like a plant or an alga. Some biochemical evidence favors interpretation as an alga. Lignin and cutin have been found in the thalli, and sporopollenin in the spore walls.[:64] The grouping of the spores found in the thallus favors interpretation as a plant. The absence of any stomata on the surface is inconclusive, as all bryophytes lack stomata on the main body of the plant.

However, the tips of *Protosalvinia* branches show evidence of conceptacle-like dips.[:64]

Protosalvinia is found in association with conodont elements.

For the present, the relationships of *Protosalvinia* remain uncertain.

Psilophyton



Psilophyton is a fossil genus which currently contains seven species known mostly from compression, impression and some permineralized anatomy. Most specimens come from northern Maine, Gaspé Bay in Quebec, New Brunswick and the Czech Republic. *P. princeps*, *P. forbesii*, *P. dapsile*, *P. charientos*, *P. dawsonii*, *P. microspinosum*, *P. kräuselii* and *P. crenulatum* are the currently accepted members of the genus Psilophyton. Variation within the genus is significant.. The average specimen was 60 cm or more tall.

Cordaites

Cordaites is an important genus of extinct gymnosperms which grew on wet ground similar to the Everglades in Florida. Brackish water mussels and crustacea are found frequently between the roots of these trees. The fossils are found in rock sections from the Upper Carboniferous of the Dutch - Belgian - German coal area. A number of many noteworthy types from this line are:

- *Cordaites principalis*
- *Cordaites ludlowi* (named after Ludlow, a coal area in England)

In contrast to many other plant varieties, Cordaites seeds are not rare, because they are rather large (up to 10mm); those seeds are named Cordaicarpus.

Jardin des Plantes of Paris, France. Glasshouses. September 2010

Araucarioxylon arizonicum

Araucarioxylon arizonicum is an extinct species of conifer that is the state fossil of Arizona. The species is known from massive tree trunks that weather out of the Chinle Formation in desert badlands of northern Arizona and adjacent New Mexico, most notably in the 378.51 square kilometres (93,530 acres) Petrified Forest National Park. There, these trunks are locally so abundant that they have been used as building materials.

In the Triassic period Arizona was a flat tropical expanse in the northwest corner of the supercontinent Pangaea. There, a forest grew in which *A. arizonicum* towered as high as 60 metres (200 ft) and measured more than 60 centimetres (2.0 ft) in diameter. Fossils frequently show boreholes of insects.

The petrified wood of this tree is frequently referred to as "Rainbow wood" because of the large variety of colors some specimens exhibit. The red and yellow are produced by large particulate forms of iron oxide, the yellow being limonite and the red being hematite. The purple hue comes from extremely fine spherules of hematite distributed throughout the quartz matrix, and not from manganese, as has sometimes been suggested.

Agate House Pueblo, constructed with petrified wood

Queries about the validity of this name

In December 2008 W.P. Armstrong expressed doubts about the validity of the biological name *Araucarioxylon arizonicum*.

Abies milleri

Abies milleri
Fossil range: 49.5 Ma

Fossil *Abies milleri* foliage and axis

Scientific classification

Kingdom:	Plantae
Division:	Pinophyta
Class:	Pinopsida
Order:	Pinales
Family:	Pinaceae
Genus:	*Abies*
Species:	***A. milleri***

Binomial name

Abies milleri
Schorn & Wehr

Abies milleri, an extinct species of fir known from fossil remains found in the early Eocene Ypresian stage deposits in Washington State, USA, is the oldest confirmed record for the fir genus. The species was described from 81 fossil specimens collected from Burke Museum site number A0307 in Ferry County, Washington. The holotype specimen, number # *UWBM 31299*, and the eleven paratype specimens are currently deposited in the collections of the Burke Museum in Seattle, where they were studied and described by Howard E. Schorn and Wesley C. Wehr. Schorn and Wehr published their 1986 type description for *A. milleri* in the *Burke Museum Contributions in Anthropology and Natural History*, Volume 1. The specific epithet, *milleri*, was coined in honor of Charles N. Miller Jr for his contributions to the study and understanding of the conifer family Pinaceae. The studied specimens were excavated from the Tom Thumb Tuff member of the Klondike Mountain Formation in the city of Republic.

A. milleri has been placed in the Fir genus *Abies*, which has between 48 and 55 species native to much of North and Central America, Europe, Asia, and North Africa, occurring in mountains over most of the range. The characters used to separate extant species of *Abies* are based on the reproductive structures such as cone scales, wing seeds and bracts. The placement in *Abies* is based on the dorso-ventrally flattened leaves, and the circular leaf scars, which separate the organs from those of *Pseudotsuga* and *Keteleeria*. Within *Abies*, *A. milleri* shows similarities with *A. kawakamii* and *A. chensiensis* from Asia and with *A. concolor* and *A. lasiocarpa* of North America. *A. milleri* does not show traits which allow placement in any one of *Abies* genus sections, however.

The 81 specimens studied for the *A. milleri* description included 40 cone scales, 21 wing seeds, 10 foliated axes, and two detached needles. Schorn and Wehr placed the different detached organ fossils in the same species based on a number of factors. Where visible, all the cone scales have bracts and are morphologically similar. The scales display impressions on the admedial surface of wing seeds that match the fossil seed dimensions. The needle arrangement is consistent on both foliated and defoliated axes, with attached needles matching isolated needles. All of the fossils occurred in the same stratigraphic layers.

The cone scales up to 32 by 20 millimetres (1.3 by 0.79 in) and 1.25-2 times as long as wide, have a generally triangular to cuneate shape with the distal edge turned upwards and the stalk on half the length of the scale. Sometimes preserved with cone scales are the bracts which average 5 by 4 millimetres (0.20 by 0.16 in) and have a central accuminate flanked by thinner laminae. The wing seeds are up to 27 by 14 millimetres (1.1 by 0.55 in) and have a pterostegium which covers on average three-quarters of the seed. The narrow obovate seed is generally 12 by 4 millimetres (0.47 by 0.16 in), 1-1.5 times the length of the upper wing edge while the wing itself is widest in the distal half. Needles of *A. milleri* reach up to 38 millimetres (1.5 in) long, but have a width of only 1 millimetre (0.039 in) at the base. The leaf base is generally as wide to slightly wider than the leaf and round, with the leaf angled approximately 70 degrees upward from the attachment. Leaf scars on axes are circular to slightly oval, 1.5 by 2 millimetres (0.059 by 0.079 in), and show a vascular bundle scar in the center. Oval leaf scars are oriented with the long axis parallel to the length of the stem axis. While the scars show the leaves to be in a helical arrangement, the leaves would have had a flattened orientation on either side of the axis.

Corylus johnsonii

Corylus johnsonii

Corylus johnsonii holotype specimen

Scientific classification

Kingdom:	Plantae
Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Fagales
Family:	Betulaceae
Genus:	*Corylus*
Species:	**†*C. johnsonii***

Binomial name

Corylus johnsonii
Pigg, Manchester, & Wehr, 2003

Corylus johnsonii is an extinct species of hazel known from fossil fruits found in early Eocene Ypresian stage Klondike Mountain Formation deposits of Northern Washington State. Based on described features, *C. johnsonii* is the oldest definite species in the genus *Corylus*.

The description of the new species by Dr. Kathleen Pigg, Steven Manchester, and Wesley Wehr was based on the study of thirty-four compression fossil specimens found at the UWBM sites B4131 and A0307, the latter being designated the type locality. The specimens are twelve infructescences with attached involucres containing nuts or nut casts, fourteen involucres, and eight isolated paired or single nuts. The holotype specimen is number "SR 98-01-02 A&B", an infructescence with involucre, and is housed in the Stonerose Interpretive Center in Republic, Washington. The species epithet *johnsonii* was coined in honor of Kirk R. Johnson for his continuing work on, and recognition of the importance of, the Republic Flora.

The infructescences bear between 2 and 3 nuts at the end of a stout stalk. The nuts, 8 to 17 millimetres (0.31 to 0.67 in) in diameter, are ovoid to almost circular in outline and enclosed in an involucre composed of 2 bracts. While most specimens consist of paired involucres with ovoid nuts or nut casts, several paired or isolated nuts are known. On the nuts themselves basal attachment scars cover a small area of nut; distal scars and style remains are preserved in several specimens. A predominant number of the fruits possess more dissected involucres, some having simple spines, while others have both simple and branched spines.

Though described as a single species, the authors noted the wide grade of variation in the involucre morphology, ranging from simple to ones with extensive spines. The involucres also show a spectrum from thin, leafy lobes that display distinct veins to thick lobes with no distinct venation. As specimens of *C johnsonii* have a full morphology range between the three involucre types, the possibility of multiple species is hard to prove or disprove. However the authors chose to name a single species because of the continuous gradation present between the distinct morphologies.

Of the two sections into which the genus *Corylus* is divided, section *Corylus* and section *Acanthochlamys*, *C. johnsonii* is most similar to three species in the latter. Section *Acanthochlamys* is considered basal within the genus and the three species, *Corylus ferox*, *C.wangii*, and *C. heterophylla* are all native to southeast Asia. Infructescences of *Corylus wangii*, like those of *C. johnsonii*, possess narrow lobes with many unbranched and branched spines, while *C. ferox*-like infructescences have a highly spiny, prickly surface. Specimens within the simple end of the infructescence morphologic range are most similar to *C. heterophylla*. As *C. johnsonii* encompasses a wide morphology range within its features, it is possible it may have diverged out into the modern species. The modern areas of distribution for *C.ferox* and *C. heterophylla* overlap in the Sichuan province of China, while *C. wangii* has a distinct and separate range in southwest China.

Isolated nuts from Paleocene sediments in Greenland, England, and Montana have been attributed to the *Corylus* genus. However all lack the surrounding infructescence that is needed to confirm placement of the nuts in a specific coryloid genus.

Dillhoffia

Dillhoffia **Fossil range: 49.5 Ma**

Kingdom:	Plantae
Division:	Angiospermae
Class:	*incertae sedis*
Family:	*incertae sedis*
Genus:	†***Dillhoffia***
Species:	***D. cachensis***

Binomial name

Dillhoffia cachensis
Manchester & Pigg, 2008

Dillhoffia is an extinct monotypic genus of flowering plant with a single species, ***Dillhoffia cachensis*** known from Ypresian age Eocene fossils found in British Columbia, Canada, and Washington, USA. The genus and species were described from fifteen specimens found in an unnamed formation belonging to the Kamloops group; and two specimens from the Klondike Mountain Formation. The unnamed formation outcrops at the McAbee fossil site near Cache Creek, BC, which is designated the type locality while the two U.S. specimens were recovered from the Tom Thumb Tuff member of the Klondike Mountain Formation in Republic, Washington. It is of interest to note that of the Okanagan highlands fossil sites *Dillhoffia* is only known from two locations, and is absent or has not been identified from the others.

The holotype specimen, number *TMP 83.39.175*, is preserved in the Royal Tyrell Museum and the paratype specimens are in the Thompson Rivers University and University of Saskatchewan collections. The specimens were studied by paleobotanists Steven Manchester of the University of Florida and Kathleen Pigg of Arizona State University. Manchester and Pigg published the 2008 type description for *D. cachensis* in the journal *Botany*, Volume 86, number 9. They chose the generic name *Dillhoffia* to honor the brothers Richard M. Dillhoff and Thomas A. Dillhoff for their substantial contributions and promotion of Pacific Northwest North American Paleogene floras. The specific name is a reference to Cache Creek, British Columbia, the nearest town to the McAbee site.

Dillhoffia is known from infructescences only. The infructescences are pedunculate having a globose head which bore at least twelve flowers and has been preserved as fossils with several sessile fruits. The fruits are elongate to ellipsoidal in form, being 8–10 millimetres (0.31–0.39 in) by 4–5 millimetres (0.16–0.20 in), and indehiscent. The enlarged calyx present on the fruits is thought to have been used for wind transport, with the calyx being dish to funnel shaped and born approximately three-quarters of the way up the fruit from the base. Formed from a persistant paranth, the calyx may have been accrescent, as small-sized calyces are known. It is unknown what the petals and stamens looked like, as none have been found, possibly being shed during fruit formation. *Dillhoffia* was most likely a non-magnoliid angiosperm as indicated by is inferior ovary, but placement into a specific family is not possible with the fossils known.

Trochodendron nastae

Trochodendron nastae
Fossil range: Ypresian 49.5 Ma

Trochodendron nastae specimen

Scientific classification

Kingdom:	Plantae
(unranked):	Angiospermae
(unranked):	Eudicots
Order:	Trochodendrales
Family:	Trochodendraceae
Genus:	*Trochodendron*
Species:	†***T. nastae***

Binomial name

Trochodendron nastae
Pigg, Wehr, & Ickert-Bond, 2001

Trochodendron nastae is an extinct species of flowering plant in the family Trochodendraceae known from fossil leaves found in the early Eocene Ypresian stage Klondike Mountain Formation deposits of Northern Washington State. *T. nastae* is the one of the oldest members of the genus *Trochodendron*, which includes the living species *T. aralioides*, native to Japan, southern Korea and Taiwan and the coeval extinct species *T. drachuckii* from Cache Creek, British Columbia.

Description of the new species by Dr. Kathleen Pigg, Wesley Wehr, and Stephanie Ickert-Bond was based on the study of 11 complete and 55 partial compression fossil specimens with the holotype specimen, number "SR 98-02-01", being housed in the Stonerose Interpretive Center, Republic, Washington. They published their 2001 type description of the species in the *International Journal of Plant Sciences* volume number

162. and named the species *nastae* in honor of Charlotte G. Nast for her work on extinct and living members of the Trochodendrales.

T. nastae has been placed in the genus *Trochodendron* based on the overall shape of the leaves, the secondary vein structure, which forms weak chevrons bracing primary veins, and the tertiary veins forming four to five sided cells. However the primary veins are palmate in structure for *T.nastae* rather than being pinnate as in *T. aralioides*.

Trochodendron shares with *Tetracentron* the very unusual feature in angiosperms, of lacking vessel elements in its wood. This has long been considered a very primitive character, resulting in the classification of these two genera in a basal position in the angiosperms; however, genetic research by the Angiosperm Phylogeny Group has shown it to be in a less basal position (early in the eudicots), suggesting that the absence of vessel elements is a secondarily evolved character, not a primitive one.

Banksia novae-zelandiae

Banksia novae-zelandiae
Fossil range: Oligocene–Miocene

Scientific classification

Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Eudicots
Order:	Proteales
Family:	Proteaceae
Genus:	*Banksia*
Species:	***B. novae-zelandiae***

Binomial name

Banksia novae-zelandiae
R.J.Carp., G.J.Jord., D.E.Lee & R.S.Hill

Banksia novae-zelandiae is an extinct species of *Banksia*, known only from fossil leaves found on the South Island of New Zealand.

Description

This species is based on several leaf fossils, all with triangular pinnate lobes cut all the way back to the midrib, and indistinct secondary venation. Stomata occur in areoles, and have very wrinkly subsidiary cells. Both leaf surfaces are covered in trichome bases, and the undersurface is covered in cuticular papillae.

Taxonomy

Fossil leaves were found at the Newvale Mine, Waimumu Coalfield, Southland District, South Island, New Zealand (46°8′33″S 168°45′6″E / 46.1425°S 168.75167°E), in a thin leaf litter bed located in a seam of the middle Gore Lignite Measures.

B. novae-zelandiae was first published in 2010. The specific epithet refers to New Zealand, where the fossils were found. The fossils are assigned to Banksieae based on several structural grounds, including brachyparacytic stomata, a trichome base architecture unique to Banksieae, "banksioid" venation, and the pinnate leaf lobes. Within Banksieae they are assigned to genus *Banksia* because of their cuticular papillae and the division of the leaves into triangular lobes all the way back to the midrib, neither of which occurs in any other Banksieae genus. (Before the 2007 transfer of *Dryandra* into *Banksia*, it was realised that there was no way to distinguish these two genera based solely on foliar characters, and so fossil leaves were classified into the form genera *Banksieaephyllum* and *Banksieaeformis*. Now, however, they may simply be assigned to *Banksia*.)

Although the cuticular papillae are regarded as evidence that the species belongs to *Banksia*, their unusual structure, together with some ornamentation of the trichome bases, and the absence of any features of extant *Banksia* recognised as derived, suggests that *B. novae-zelandiae* is basal to all extant *Banksia* species; that is, it belongs to the stem group of *Banksia*.

Habitat

The leaf litter bed in which *B. novae-zelandiae* was found is regarded as of late Oligocene to early Miocene origin, and is thought to have accrued in swamps associated with a coastal delta. The bed mainly contains species with sclerophyllous leaves, with no broad-leaved rainforest element in evidence, suggesting a heath-like environment. The vegetation has been interpreted as growing in a warm and constantly wet climate, and the extensive beds of lignite in the area suggest an area with poor drainage.

Biogeography

Banksia novae-zelandiae encompasses the first fossil *Banksia* material found outside Australia. It shows that the *Banksia* lineage once occurred in New Zealand, but because the species is regarded as belonging to the stem group, it does not contradict previous evidence suggesting that the crown group of *Banksia* arose in southwest Australia some time after the Paleogene.

Under the long-held view that the New Zealand flora has a Gondwanan element that has survived there at least since the Cretaceous, the presence of *B. novae-zelandiae* in New Zealand can be adequately explained by vicariance. It is harder to reconcile it with the recent claim that New Zealand was completely submerged in the late Oligocene, as this would require the unlikely (but possible) dispersal of seeds across thousands of kilometers of ocean.

Banksia kingii

Banksia kingii
Fossil range: Late Pleistocene

Banksia kingii
fossil cone

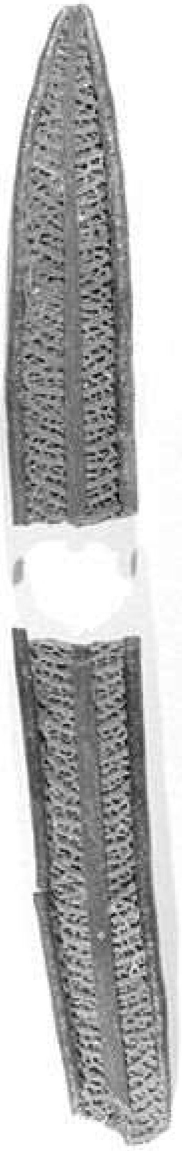
Scientific classification

Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Eudicots
Order:	Proteales
Family:	Proteaceae
Genus:	*Banksia*
Subgenus:	*Banksia*
Section:	*Banksia*
Series:	*Salicinae*
Species:	***B. kingii***

Binomial name

Banksia kingii
Jordan & Hill

Banksia kingii is an extinct species of tree or shrub in the plant genus *Banksia*. It is known only from fossil leaves and fruiting "cones" found in Late Pleistocene sediment at Melaleuca Inlet in western Tasmania. These were discovered by Deny King in the workings of his tin mine. The leaves and fruiting cones were discovered at different locations, and since the sediment had been removed during mining, the stratigraphy of the fossils is unknown. The sediment from which they were recovered was alluvial, consisting of large, well-rounded fragments of quartz and schist.



B. kingii leaf

The fossil leaves are about 12 centimetres long and one centimetre wide and very thick and robust. They clearly belong to genus *Banksia*, section *Banksia*, series *Salicinae*, but not to any of the extant species in that series. The leaves of *B. plagiocarpa* (Dallachy's

Banksia) are similar in form, shape and robustness, but differ strongly in structure. Leaves of *B. saxicola* (Grampians Banksia) are structurally the most similar to *B. kingii*, but have a different shape. There also appear to be some affinities with *B. marginata* (Silver Banksia) and *B. canei* (Mountain Banksia), but insufficient to warrant the fossil's ascription to those species. The fossils are therefore considered representative of a new species, *B. kingii*.

The fossil fruiting structures are cylindrical, about 6 centimetres high and 4½ centimetres wide. The structure had lost its old flower parts. It appears to be most closely related to *B. saxicola* and *B. canei*, with some similarities to *B. marginata*. The taxonomic situation therefore appears highly similar for both leaves and fruiting structures, and so the fruiting structures are ascribed to *B. kingii* despite the absence of any direct connection to the fossil leaves.

The species is believed to represent an extinct lineage. It is possible that it is an ancestor of *B. marginata*, although *B. marginata* must have speciated well before the extinction of *B. kingii*, given how widely it is now distributed. Extinction of *B. kingii* probably occurred in the late Quaternary, and may have been caused by the climatic and physical disruption of glaciation, or by increased fire frequency due to human activity.

A formal description of *B. kingii* was published in 1991 by Gregory J. Jordan and Robert S. Hill, who named the species in honour of the discover, Deny King. Hence the species' full name is "*Banksia kingii* Jordan & Hill". The holotype and a number of other specimens are stored in the Department of Plant Science at the University of Tasmania.

Chapter- 19

Encephalartos woodii

Wood's Cycad

A large stem of *Encephalartos woodii* at the Durban Botanic Gardens

Conservation status

Extinct in the Wild (IUCN 3.1)

Scientific classification

Kingdom:	Plantae
Division:	Cycadophyta
Class:	Cycadopsida
Order:	Cycadales

Family:	Zamiaceae
Genus:	*Encephalartos*
Species:	***E. woodii***

Binomial name

Encephalartos woodii
Sander

Wood's Cycad (*Encephalartos woodii*) is a cycad in the genus *Encephalartos*, and is endemic to the Ongoye Forest of KwaZulu-Natal, South Africa. It is one of the rarest plants in the world, being extinct in the wild with all specimens being clones of the type. The specific and common name both honour John Medley Wood, curator of the Durban Botanic Garden and director of the Natal Government Herbarium of South Africa, who discovered the specimen in 1895.

Cone of *Encephalartos woodii*

Portion of a leaf showing leaflets

Description

It is palm tree like, and can reach a height of 6 metres (20 ft). The trunk is about 30–50 centimetres (12–20 in) in diameter, thickest at the bottom, and topped by a crown of 50–150 leaves. The leaves are glossy and dark green, 150–250 centimetres (59–98 in) in length, and keeled with 70–150 leaflets, the leaflets falcate (sickle-shaped), 13–15 centimetres (5–6 in) long and 20–30 millimetres (0.8–1 in) broad.

E. woodii is dioecious, meaning it has separate male and female plants, however no female plant has ever been discovered. The male strobili are cylindrical, 20–40 centimetres (7.9–16 in) long, exceptionally up to 120 centimetres (47 in), and 15–25 centimetres (6–10 in) in diameter; they are a vivid yellow-orange colour. A single plant may bear from around six to eight simultaneously.

Taxonomy

Encephalartos woodii was first described by Wood as a variety of *E. altensteinii* (as *E. altensteinii* var. *bispinna*), and raised to the rank of species in 1908 by the English horticulturalist Henry Sander from studying a specimen in his collection, which was apparently one of the basal offsets taken from the original clump. It has been considered that *Encephalartos woodii* is most closely related to *E. natalensis*. Some authorities consider *E. woodii* to not be a true species but rather a mutant *E. natalensis* or a relic of some other species. Yet others consider this plant to be a natural hybrid between *E. natalensis* and *E. ferox*. To determine the relationship between *E. natalensis* and *E. woodii*, the RAPD technique was used to generate genetic fingerprints and data analysed using distance methods. Based on RAPD fingerprints, the intraspecific genetic variation among different *E. natalensis* plants is similar to the interspecific variation between *E. natalensis* and *E. woodii*, which confirms the close relationship between *E. natalensis* and *E. woodii*.

Distribution and Habitat

The last two stems of Wood's Cycad at Ongoye in the early 1900's

One of the original stems in the Durban Botanic Gardens

Another large stem of *E. woodii* at the Durban Botanic Gardens

Original Distribution

The only known wild plants of *E. woodii* were a cluster of four stems of one plant discovered by Wood in 1895 in a small area of Ngoya Forest, now known by its proper Zulu name of *Ongoye*, which is in KwaZulu-Natal, South Africa. The site where this plant was found was on a steep south-facing slope on the fringes of the forest. The annual rainfall at the site ranges between 750–1,000 millimetres (30–39 in), and the climate has hot summers and mild winters.

Removal from Natural Habitat

Original stem at Durban Botanic Gardens, 2010

Encephalartos woodii in the Royal Botanic Gardens, Kew

Male cone of *E. woodii* in California

A basal offset of the main stems was removed and sent to Kew Gardens in 1899. Three basal offsets were collected by Wood's deputy, James Wylie, in 1903 and planted in the Durban Botanic Gardens. One specimen was received at the National Botanic Gardens of Ireland in Glasnevin in 1905 where the register records it as "*Encephalartos way of E. Alten[steinii]*" costing 1 guinea from Sander & Sons. In a 1907 expedition, Wylie collected two of the larger stems and noted that of the remaining two, one of them (the largest of the four original stems) was badly mutilated and he did not expect it to survive. By 1912 there was only one 3 metres (9.8 ft) tall trunk left in the wild, and in 1916, the Forestry Department arranged to have it removed and sent to the Government Botanist in Pretoria. It is thought that this trunk subsequently died in 1964.

Current Distribution

These plants are currently distributed in various botanical institutions around the world. Two of the larger trunks that Wylie collected in the 1907 expedition are still to be seen in the Durban Botanic Gardens. A sucker from one of the Durban Botanic Gardens plants was sent to Kirstenbosch near Cape Town, South Africa in 1916 by James Wylie. The plant that was sent to Kew Gardens in 1899 was grown in the Palm House until April 1997 and then moved to the Temperate House where it produced, for the first time, a male cone in September 2004. In the United States; a specimen is housed in the conservatory at Longwood Gardens near Philadelphia, Pennsylvania and three specimens are to be seen at Lotus Land in Santa Barbara, California where they were planted in 1979. The specimen at Longwood Gardens was received in 1969 after a request was made to the Durban Botanic Gardens by one of Longwood's former directors, Dr. Russell Seibert, when he went on a plant exploration voyage to South Africa in the 1960s. The rooted plant was first taken to the Research Department at Longwood where the gardeners nurtured the plant until it was ready to be displayed in the Conservatory. The Longwood specimen produces cones in early winter. In Europe; a specimen is housed in the Netherlands at Hortus Botanicus in Amsterdam and in Orto Botanico di Napoli in Italy, although this specimen may have died. The specimen in Ireland at Glasnevin is said to be "probably the tallest" specimen of *E. woodii* in Europe.

Conservation Status

Despite numerous excursions in the Ongoye-Mtunzini area, no other specimens of *Encephalartos woodii* have ever been found. All known specimens of *Encephalartos woodii* are clones of the only known male plant which was completely removed from the wild. For these reasons, the plant is considered extinct in the wild.

Legislation

As is the case with all members of the genus *Encephalartos*, *Encephalartos woodii* is protected by both national and international legislation:

In South Africa one requires a permit from Nature Conservation to move, sell, buy, donate, receive, cultivate and sell Endangered Flora and to own adult cycads. On an international level all species and hybrids of *Encephalartos* are on Appendix I of CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora. This means that wild collected material may not be traded and for each and every artificially cultivated *Encephalartos* plant or piece of a plant or a cone or pollen or seed, being carried over an international border requires a CITES Export Permit issued by the authority of the exporting country, and a CITES Import Permit issued by the authority of the importing country.

Reproduction and Propagation

Offshoots (suckers) showing roots developing on the largest one

A female *E. natalensis* x *woodii* with cones

Vegetative Reproduction

Encephalartos woodii reproduces with rapidly-growing suckers.

Sexual Reproduction

Unless a female plant is found, *E. woodii* will never reproduce naturally. However, the next best thing has been accomplished. Wood's Cycad forms fertile hybrids with *E. natalensis*. If each offspring is subsequently crossed with *E. woodii* and the process is then repeated, after several generations, the female offspring will be close to what a female *Encephalartos woodii* would be like. Genetic analysis of chloroplast DNA of F1 hybrids between *E. woodii* and *E. natalensis* showed that all chloroplasts are inherited from the female *E. natalensis*, indicating that multigenerational hybrid offspring would have *E. natalensis* chloroplasts and could never be "pure" *E. woodii*.

Distribution of Hybrids

Encephalartos natalensis x *E. woodii* at Orto botanico di Palermo

Several hybrids between *E. woodii* and other species of *Encephalartos* have been produced including:

- *Encephalartos gratus* x *E. woodii* at Lotus Land, California.
- *Encephalartos natalensis* x *E. woodii* at Orto botanico di Palermo in Italy, and in various collections in South Africa and the United States.
- *Encephalartos transvenosus* x *E. woodii* in collections in South Africa and the United States.