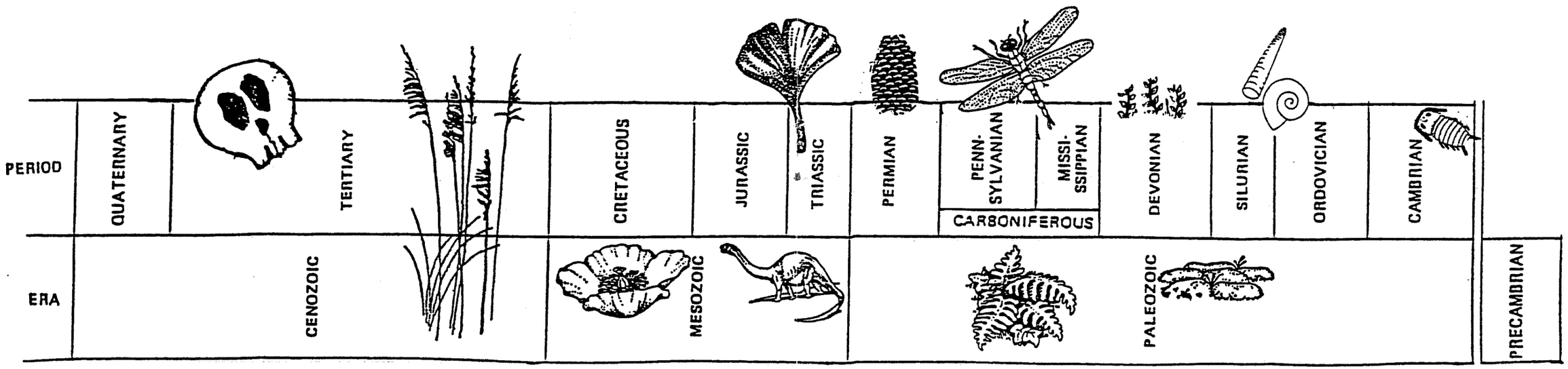
contrast, the earliest "colonizers" of the land most likely were quite dependent on water. Water was important to their existence: providing nutrients and protection from ultraviolet rays, and in removing waste products. In the late Silurian, green algae gave rise to the first vascular land plants. These plants had a waxy covering (cuticle) and a vascular system to transport water and nutrients within the plant. The earliest vascular plants also had structures at the tips of their leafless stems that produced spores. The spores, somewhat resistant to drying out, were spread by the wind for reproduction. In our display we have several **3** specimens of *Psilotum*, a shrubby plant whose features - no leaves, no roots, and sporangia clustered at the ends of short branches - remind us of the early land plants. Sporangia are hollow structures in which spores are produced.

The Devonian period, beginning 410 million years ago, was a time of rapid evolution of land plants. Partially decaying plant matter supplied nutrients for growth. Plants began to increase in size and many of the features that we associate with modern plants appeared. For example, the lycopods and their immediate ancestors, were the first to develop leaves. By the end of this period plants had well developed roots and tree-like forms contained wood. Sometime near the end of the Devonian, certain plants developed seeds. Seeds are unique structures because a tiny embryo from the parent plant is enclosed with a food supply within a protective coat.

Forests covered the land during the Carboniferous, or Mississippian and Pennsylvanian periods (beginning 360 million years ago). Probably everyone has a visual image of a Carboniferous swamp, characterized by rich soil, humid climate and plenty of moisture. Giant-sized lycopods, horsetails, ferns, and fern-like plants that produced seeds were dominant. **4** Other seed producing plants existed that have no living descendants in our modern world. Fossils confirm the existence of cordaites. Many of the cordaites were highly branched trees. At the tips of the youngest branches huge straplike leaves (up to 3 ft.long) were arranged in spirals. In our display, living representatives of the plants from these Devonian and Carboniferous forests are ferns, horsetails, lycopods, and liverworts. Our tree fern *(Sphaeropteris cooperi)* **5** is a very distant relative of those present during the Carboniferous.

The end of the Carboniferous period marked the demise of moisture-loving plants. Conditions would become drier and more seasonal during the Permian period (beginning 290 million years ago). Plants with seeds would have an advantage over the water-loving ferns and lycopods. Conifers (pines, spruces) that appeared during the late Carboniferous became more common. Cycads (sago palm) also appeared. Ginkgo-like plants made their first appearance. You may be familiar with "the living fossil", *Ginkgo biloba*, a tree known only in cultivation. It has distinctive fan-shaped leaves that are notched. These vascular plants are often called gymnosperms, which means "naked seed". Gymnosperm



seeds are not enclosed in a protective fruit. The gymnosperms would become the dominant plants of the Triassic and Jurassic periods (beginning 250 million years ago). Our display has several examples of living cycads **6** and other gymnosperms **7**.

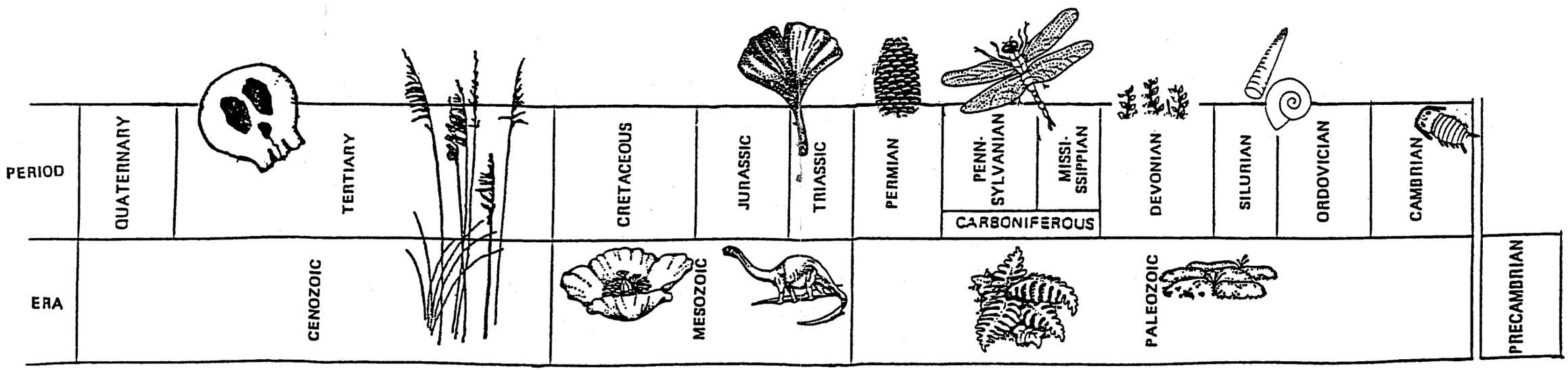
Flowering plants finally appeared in the Cretaceous period (beginning 144 million years ago). At the beginning of this period the plant world was dominated by ferns and gymnosperms. Flowering plants diversified so rapidly that by the end of this period many plants existed that had the same features their descendants have today. The fossil record confirms the existence of leaves, pollen and flowers. Flowering plants are called angiosperms, meaning "container seed". All angiosperms have seeds present in fruits. During this time period, reproductive success increased as plants were pollinated by wind, insects and animals. The seed-bearing fruits were then dispersed by animals and insects. Living angiosperms are highly variable in appearance. **8** Our display illustrates the amazing variability of the angiosperms, including fruit trees, orchids, grasses, palms, cacti, bamboo, aster, magnolia.....

Mass extinction occurred at the end of the Cretaceous period. Many organisms disappeared, specifically the dinosaurs, flying reptiles, and many land plants. The Tertiary period (beginning 65 million years ago) was a time of

1 The story of plant evolution begins in the ancient seas of the Earth. B sulfur bacteria and cyanobacteria (blue green bacteria) existed in ancient seas approximately 3.5 billion years ago. These organisms were able to produce oxygen through the process of photosynthesis, where energy from the sun is used to produce sugar (glucose). Plants, algae and photosynthetic bacteria are the only organisms that have the ability to capture energy from the sun to make organic molecules that all organisms need to live. Oxygen is released as a by-product of this process. The release of free oxygen into these ancient seas would ultimately change the environment of our primitive Earth, setting the stage for the movement of life from the sea to land.

Fossils from the Paleozoic Era (beginning 545 million years ago) provide us with evidence for the existence of many types of algae. Life in the seas continued to diversify, with the colonization of the land by higher plants delayed until the Silurian period (approximately 435 million years ago). During the Silurian period the coastline moved back and forth as sea levels fluctuated, providing the opportunity for the colonization of the land. By this time the ozone layer had formed from the oxygen produced by the photosynthetic organisms growing in the seas. What adaptations would be necessary for life on land?

2 Plants would need to take in and transport water and nutrients, protect themselves from water loss and be able to reproduce in drier environments. In



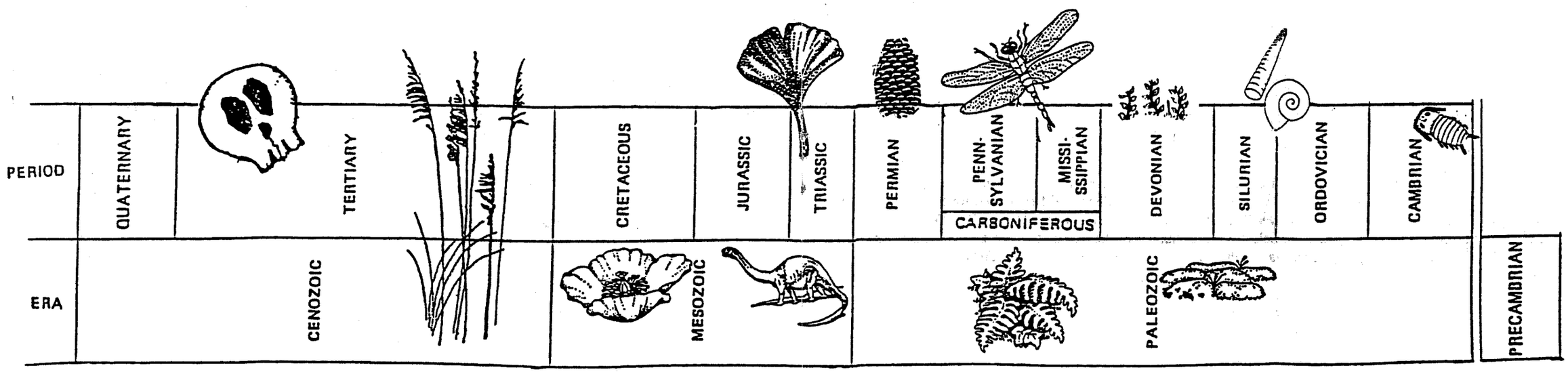
To use this guide to interpret this Lobby Court display, please follow the red numbers. These numbers will enable you to embark on a journey through the evolution of plants on Earth. The numbers are located on both the aquarium tanks and in the Lobby Court bed.

If you look around the world today, you will see that flowering plants represent approximately 80% of the 250,000 known species of land plants. But, for millions of years, the Earth was totally devoid of land plants. Of all the plants that are alive today, the seaweeds and pond scums suggest the type of vegetation found on Earth before plants could tolerate exposure to the sun, rapid changes in temperature and other features of terrestrial existence. This lobby court display uses living plants to illustrate some of the major milestones in plant evolution. Before plants colonized the land, the earth had no soil and no shade. The first land plants are important because they provide an environment for the subsequent invasion of land animals.

Today, life on this planet is protected by the ozone layer in the outer atmosphere. Ozone (O_3) acts as a filter, removing most of the destructive ultraviolet rays coming from the sun. Several lines of evidence suggest that the primitive atmosphere of our planet consisted largely of carbon dioxide (CO_2). How did the ozone layer form?

climate change. Global warming fr[illegible] high levels of carbon dioxide in[illegible] atmosphere contributed to higher temperatures on land. Many new plants appeared in response to warmer climates. Following this warming, the climate became cooler and drier. As the diversity of the conifers declined across the landscape, angiosperms with herbaceous growth habits (grasses) became more common. **9** By the end of the Tertiary period, tropical and temperate ecosystems were forming. The earliest human ancestor, "Lucy", *(Australopithecus afarensis)* is thought to have existed 4 million years ago.

Today, the variety of life on Earth is impressive: so far, scientists have described about 1.4 million species of plants, animals, insects and fungi. Despite these numbers, there are many, many species that remain unknown. Unfortunately, due to habitat destruction, pollution, and over consumption of natural resources, the extinction rate is estimated to be 3 species per day. **You** are the only creature on the planet that can think about the value of the history of life on Earth. Do what you can to preserve healthy ecosystems for future generations!



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Especially for children:

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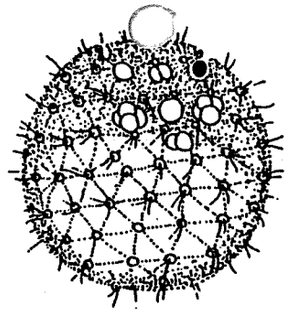
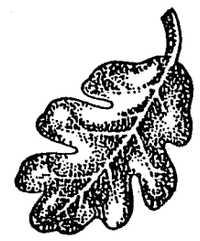
Denver Botanic Gardens gratefully acknowledges the Denver Museum of Natural History, especially Dr. Kirk Johnson, for selecting and arranging for the plant fossils for this exhibit.

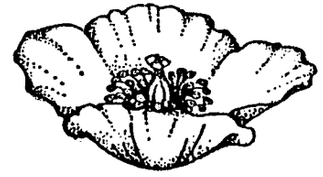
SCFD
Scientific & Cultural Facilities District

Denver Botanic Gardens and Chatfield Arboretum are established and maintained by Denver Botanic Gardens, Inc., for the people of the City and County of Denver and for the general public in cooperation with the Denver Parks and Recreation Department. Denver Botanic Gardens is also grateful for funds from the Scientific & Cultural Facilities District (SCFD), which enable the Gardens to expand services and enhance the quality of programs and exhibits.



From Algae to Angiosperms





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