Paleontology

Unit 5

Vertebrate paleontology

Vertebrate paleontology is the subfield of paleontology that seeks to discover, through the study of fossilized remains, the behavior, reproduction and appearance of extinct animals with vertebrae or a notochord. . It also tries to connect, by using the evolutionary timeline, the animals of the past and their modern-day relatives.

The fossil record shows aspects of the meandering evolutionary path from early aquatic vertebrates to mammals, with a host of transitional fossils, though there are still large blank areas. The earliest known fossil vertebrates were heavily armored fish discovered in rocks from the Ordovician Period about 500 to 430 Ma (megaannum, million years ago). The Devonian Period (395 to 345 Ma) brought in the changes that allowed primitive air-breathing fish to remain on land as long as they wished, thus becoming the first terrestrial vertebrates, the amphibians.

Classification of vertebrate paleontology

The "traditional" vertebrate classification scheme employ evolutionary taxonomy where several of the taxa listed are paraphyletic, i.e. have given rise to another taxa that have been given the same rank. For instance, birds are generally considered to be the descendants of reptiles (Saurischian dinosaurs to be precise), but in this system both are listed as separate classes.

Phylum Chordata (vertebrates)

- Class Agnatha (jawless fish)
  - Subclass Cyclostomata (hagfish and lampreys)
  - Subclass Ostracodermi (armoured jawless fish) †
- Class Chondrichthyes (cartilaginous fish)
  - Subclass Elasmobranchii (sharks and rayes)
  - Subclass Holocephali (chimaeras and extinct relatives)
- Class Placodermi (armoured fish) †
- Class Acanthodii ("spiny sharks", sometimes classified under bony fishes) †
- Class Osteichthyes (bony fish)
  - Subclass Actinopterygii

    - Subclass Sarcopterygii
- Class Amphibia
    - Subclass Labyrinthodontia †
    - Subclass Lepospondyli †
    - Subclass Lissamphibia

Evolution of vertebrates through geological time

The earliest vertebrates were jawless fish, similar to living hagfish. They lived between 500 and 600 million years ago. They had a cranium but no vertebral column.

Amphibians, reptiles, mammals, and birds evolved after fish.

- The first amphibians evolved from a lobe-finned fish ancestor about 365 million years ago. They were the first vertebrates to live on land, but they had to return to water to reproduce. This meant they had to live near bodies of water.
- The first reptiles evolved from an amphibian ancestor at least 300 million years ago. They laid **amniotic eggs** and had internal fertilization. They were the first vertebrates that no longer had to return to water to reproduce. They could live just about anywhere.
- Mammals and birds both evolved from reptile-like ancestors. The first mammals appeared about 200 million years ago and the earliest birds about 150 million years ago.

Introduction to Dinosaurs

The prehistoric reptiles known as dinosaurs arose during the Middle to Late Triassic Period of the Mesozoic Era, some 230 million years ago. They were members of a subclass of reptiles called the archosaurs ("ruling reptiles"), a group that also includes birds and crocodiles.

Since then, dinosaur fossils have been found all over the world and studied by paleontologists to find out more about the many different types of these creatures that existed. Scientists have traditionally divided the dinosaur group into two orders: the "bird-hipped" Ornithischia and the "lizard-hipped" Saurischia. From there, dinosaurs have been broken down into numerous genera (e.g. Tyrannosaurus or Triceratops) and each genus into one or more species. Some dinosaurs were bipedal, which means they walked on two legs. Some walked on four legs (quadrupedal), and some were able to switch between these two walking styles. Some dinosaurs were covered with a type of body armor, and some probably had feathers, like their modern bird relatives. Some moved quickly, while others were lumbering and slow. Most dinosaurs were herbivores, or plant-eaters, but some were carnivorous and hunted or scavenged other dinosaurs in order to survive.

At the time the dinosaurs arose, all of the Earth's continents were connected together in one land mass, now known as Pangaea, and surrounded by one enormous ocean. Pangaea began to break apart into separate continents during the Early Jurassic Period (around 200 million years ago), and dinosaurs would have seen great changes in the world in which they lived over the course of their existence. Dinosaurs mysteriously disappeared at the end of the Cretaceous Period, around 65 million years ago. Many other types of animals, as well as many species of plants, died out around the same time, and numerous competing theories exist as to what caused this mass extinction. In addition to the great volcanic or tectonic activity that was occurring around that time, scientists have also discovered that a giant asteroid hit Earth about 65.5 million years ago, landing with the force of 180 trillion tons of TNT and spreading an enormous amount of ash all over the Earth's surface. Deprived of water and sunlight, plants and algae would have died, killing off the planet's herbivores; after a period of surviving on the carcasses of these herbivores, carnivores would have died out as well.

Despite the fact that dinosaurs no longer walk the Earth as they did during the Mesozoic Era, unmistakable traces of these enormous reptiles can be identified in their modern-day descendants: birds. Dinosaurs also live on in the study of paleontology, and new information about them is constantly being uncovered. Finally, judging from their frequent appearances in the movies and on television, dinosaurs have a firm hold in the popular imagination, one realm in which they show no danger of becoming extinct.

Indian dinosaurs

This is a **lists of dinosaurs** whose remains have been recovered from the **Indian subcontinent or Madagascar**. Though widely separated today, the Indian subcontinent and Madagascar were connected throughout much of the Mesozoic and shared similar dinosaur faunas, distinct from what has been found on other modern African and Asian landmasses.

The Indian fossil record of dinosaurs is good, with fossils coming from the entire Mesozoic era – starting with the Triassic period (a geological period that started 251.9 million years ago and continued till 201.3 million years ago), to the Jurassic period (201 million years ago to 145 million years ago) and Cretaceous period (from 145 million years ago to 66 million years ago), when globally all non-avian dinosaurs and 65 per cent of all life became extinct. [1] Madagascar also preserves various unique dinosaurs from the Jurassic and Cretaceous.

Kotasaurus

kotasaurus is a genus of sauropod dinosaur from the Early Jurassic period (Sinemurian–Pliensbachian[1]). The only known species is *Kotasaurus yamanpalliensis*. It was discovered in the Kota Formation of Telangana, India and shared its habitat with the related *Barapasaurus*. So far the remains of at least 12 individuals are known. The greater part of the skeleton is known, but the skull is missing, with the exception of two teeth.[2] Like all sauropods, it was a large, quadrupedal herbivore with long neck and tail.

Rajasaurus

Rajasaurus is a genus of carnivorous abelisaurid theropod dinosaur from the Late Cretaceous of India, containing one species: *Rajasaurus narmadensis*. The bones were excavated from the Lameta Formation in the Gujarat state of Western India, probably inhabiting what is now the Narmada River Valley. It was formally described by palaeontologist Jeffrey A. Wilson and colleagues in 2003 based on a partial skeleton comprising the braincase, spine, hip bone, legs, and tail–a first for an Indian theropod. The dinosaur likely measured 6.6 metres (22 ft), and had a single horn on the forehead which was probably used for display and head-butting. Like other abelisaurids, *Rajasaurus* was probably an ambush predator.

Stegosaurus

Stegosaurus :*stegos* which means roof, and *sauros* (σαῦρος), which means lizard, is a genus of herbivorous thyreophoran dinosaur. Fossils of this genus date to the Late Jurassic period, where they are found in Kimmeridgian to early Tithonian aged strata, between 155 and 150 million years ago, in the western United States and Portugal. Of the species that have been classified in the upper Morrison Formation of the western US, only three are universally recognized; ***S. stenops***, ***S. ungulatus*** and ***S. sulcatus***. The remains of over 80 individual animals of this genus have been found. *Stegosaurus* would have lived alongside dinosaurs such as *Apatosaurus*, *Diplodocus*, *Brachiosaurus*, *Allosaurus*, and *Ceratosaurus*; the latter two may have preyed on it.

These were large, heavily built, herbivorous quadrupeds with rounded backs, short fore limbs, long hind limbs, and tails held high in the air. Due to their distinctive combination of broad, upright plates and tail tipped with spikes, *Stegosaurus* is one of the most recognizable kinds of dinosaurs. The function of this array of plates and spikes has been the subject of much speculation among scientists. Today, it is generally agreed that their spiked tails were most likely used for defense against predators, while their plates may have been used primarily for display, and secondarily for thermoregulatory functions. *Stegosaurus* had a relatively low brain-to-body mass ratio. It had a short neck and a small head, meaning it most likely ate low-lying bushes and shrubs. One species, *Stegosaurus ungulatus*, is the largest known of all the stegosaurians (bigger than related dinosaurs such as *Kentrosaurus* and *Huayangosaurus*).

Ankylosaurus

Ankylosaurus is a genus of armored dinosaur. Its fossils have been found in geological formations dating to the very end of the Cretaceous Period, about 68–66 million years ago, in western North America, making it among the last of the non-avian dinosaurs. It was named by Barnum Brown in 1908; the only species in the genus is ***A. magniventris***. The genus name means "fused lizard", and the specific name means "great belly". A handful of specimens have been excavated to date, but a complete skeleton has not been discovered. Though other members of Ankylosauria are represented by more extensive fossil material, *Ankylosaurus* is often considered the archetypal member of its group, despite having some unusual features.

Archaeopteryx

oldest known fossil bird. The specimens date to approximately 150 million years ago, during the Late Jurassic Epoch (163.5 million to 145 million years ago), and all were found in the Solnhofen Limestone Formation in Bavaria, Germany, starting in 1861. However, late 20th- and early 21st-century discoveries of other birdlike fossils of similar age, including *Xiaotingia zhengi* from the Liaoning deposits in China, have prompted several paleontologists to call for the reclassification of *Archaeopteryx* as a dinosaur.

Much of what is known about *Archaeopteryx* comes from a series of well-preserved fossil specimens. The Solnhofen Limestone is a very fine-grained Jurassic limestone formed in a shallow tropical marine environment (probably a coral lagoon), where lime-rich muds slowly accumulated and permitted fossil material to be exceptionally well preserved. Several of the fossils show clear impressions of feathers. The sizes of the specimens range from that of a blue jay to that of a large chicken.

Archaeopteryx shared many anatomic characters with coelurosaurs, a group of theropods (carnivorous dinosaurs). In fact, only the identification of feathers on the first known specimens indicated that the animal was a bird. Unlike living birds, however, *Archaeopteryx* had well-developed teeth and a long well-developed tail similar to those of smaller dinosaurs, except that it had a row of feathers on each side. The three fingers bore claws and moved independently, unlike the fused fingers of living birds. *Archaeopteryx* had well-developed wings, and the structure and arrangement of its wing feathers—similar to that of most living birds—indicate that it could fly. However, evidence suggests that the animal's powered flight differed from that of most modern birds. The bones of *Archaeopteryx* were strong enough to handle low torsional forces, which allowed for bursts of powered flight over short distances to elude predators, rather than high torsional forces, which are required for rapid flapping and soaring. A study of melanosomes (the pigmented, melanin-producing granules present in specialized skin cells called melanocytes) in the animal's feathers revealed that the feathers were black and that the arrangement of the granules within the feather's microstructure probably provided increased structural support to the wings, similar to the way it does in modern birds. Skeletal structures related to flight are incompletely developed, however, which suggests that *Archaeopteryx* may not have been able to sustain flight for great distances. *Archaeopteryx* is known to have evolved from small carnivorous dinosaurs, as it retains many features such as teeth and a long tail. It also retains a wishbone, a breastbone, hollow thin-walled bones, air sacs in the backbones, and feathers, which are also found in the nonavian coelurosaurian relatives of birds. These structures, therefore, cannot be said to have evolved for the purpose of flight, because they were already present in dinosaurs before either birds or flight evolved.

Pterosaurs

Pterodactyl is the common term for the winged reptiles properly called pterosaurs, which belong to the taxonomic order Pterosauria. Scientists typically avoid using the term and concentrate on individual genera, such as *Pterodactylus* and *Pteranodon*.

There are at least 130 valid pterosaur genera, according to David Hone, a paleontologist at Queen Mary University of London. They were widespread and lived in numerous locations across the globe, from China to Germany to the Americas.

Pterosaurs first appeared in the late Triassic Period and roamed the skies until the end of the Cretaceous Period (228 to 66 million years ago), according to an article published in 2008 in the German scientific journal Zitteliana. Pterosaurs lived among the dinosaurs and became extinct around the same time, but they were not dinosaurs. Rather, pterosaurs were flying reptiles. Modern birds didn't descend from pterosaurs; birds' ancestors were small, feathered, terrestrial dinosaurs.

The first pterosaur discovered was *Pterodactylus*, identified in 1784 by Italian scientist Cosimo Collini, who thought he had discovered a marine creature that used its wings as paddles. A French naturalist, Georges Cuvier, proposed that the creatures could fly in 1801, and then later coined the term "Ptero-dactyle" in 1809 after the discovery of a fossil skeleton in Bavaria, Germany. This was the term used until scientists realized they were finding different genera of flying reptiles. However, "pterodactyl" stuck as the popular term.*Pterodactylus* comes from the Greek word *pterodaktulos*, meaning "winged finger," which is an apt description of its flying apparatus. The primary component of the wings of *Pterodactylus* and other pterosaurs were made up of a skin and muscle membrane that stretched from the animals' highly elongated fourth fingers of the hands to the hind limbs.

The reptiles also had membranes running between the shoulders and wrists (possibly incorporating the first three fingers of the hands), and some groups of pterosaurs had a third membrane between their legs, which may have connected to or incorporated a tail.

Early research suggested pterosaurs were cold-blooded animals that were more suited to gliding than active flying. However, scientists later discovered that some pterosaurs, including *Sordes pilosus* and *Jeholopterus ninchengensis*, had furry coats consisting of hairlike filaments called pycnofibers, suggesting they

were warm-blooded and generated their own body heat, according to a 2002 study in the Chinese Science Bulletin.
What's more, a 2010 study in the journal PLOS ONE suggested pterosaurs had powerful flight muscles, which they could use to walk as quadrupeds (on all fours) like vampire bats and vault into the air. Once airborne, the largest pterosaurs (*Quetzalcoatlus northropi*) could reach speeds of over 67 mph (108 kph) for a few minutes and then glide at cruising speeds of about 56 mph (90 kph), the study found.

Sizes of pterosaurs

Pterodactylus antiquus (the only known species of the genus) was a comparatively small pterosaur, with an estimated adult wingspan of about 3.5 feet (1.06 meters), according to a 2012 study in the journal Paläontologische Zeitschrift. There was some confusion early on as to the size of the *Pterodactylus*, because some of the specimens turned out to be juveniles rather than adults.
The smallest pterosaur, called *Nemicolopterus crypticus*, was discovered in the western part of China's Liaoning Province. It had a wingspan of only 10 inches (25 centimeters), according to a description of the animal, published 2008 in the journal Proceedings of the National Academy of Sciences.
One of the largest pterosaurs is believed to be *Quetzalcoatlus northropi,* whose wingspan reached 36 feet (11 m), according to the 2010 PLOS ONE article.
Another large pterosaur was *Coloborhynchus capito*, which had a wingspan of about 23 feet (7 m).
Characteristics
Given the large number of different types of pterosaurs, the physical characteristics of the winged reptiles varied widely depending on the genera.

Pterosaurs often had long necks, which sometimes had throat pouches similar to pelicans' for catching fish. Most pterosaur skulls were long and full of needlelike teeth. However, pterosaurs of the taxonomic family Azhdarchidae, which ruled the Late Cretaceous skies and included *Quetzalcoatlus northropi*, were toothless, according to a 2014 study in the journal ZooKeys.
A distinguishing feature of pterosaurs was the crest on their heads. Though it was initially thought that pterosaurs had no crests, it's now known that crests were widespread across pterosaur genera and came in various forms.

For instance, some pterosaurs had big, bony crests, while other crests were fleshy with no underlying bone. Some pterosaurs even appear to have had a saillike crest made up of a membrane sheet connecting two large bones on the head. "We now know that pterosaur crests had all kinds of [bone and flesh] combinations," Hone told Live Science.

There are several lines of evidence that support this function of the crests, Hone explained, perhaps most notably that juveniles, which look like miniature versions of adult pterosaurs, don't have crests, suggesting the structures are used for something that is only relevant to adults, such as mating.

Palaeobotany

Paleobotany, which is also spelled as **palaeobotany**, is the branch of botany dealing with the recovery and identification of plant remains from geological contexts, and their use for the biological reconstruction of past environments (paleogeography), and the evolutionary history of plants, with a bearing upon the evolution of life in general.

Classification of plant fossil

Plant fossils are classified into two groups: (1) macrofossils, which are the larger plant members, such as stems and leaves, usually detached and often fragmented; and (2) microfossils, which are the shells or resistant outer walls of minute plants, such as diatoms, or of pollen grains and spores. Fruits and seeds vary considerably in size and overlap each group.

For several reasons pollen and spores have a particular importance in present-day geological research in New Zealand. (1) Being produced in large numbers, readily dispersed, and highly resistant, they are more often preserved than macrofossils. (2) They occur in sediments of terrestrial origin where no marine fossils are available, often in sufficient numbers for a comparison to be made of the relative abundance of different types. (3) Since they are also deposited in coastal waters and may be found associated with marine organisms they help to “date” sedimentary rocks in relation to marine fossil sequences.

Mode of preservation of plant fossil

Three conditions are required for the preservation of plant fossils: 1) Removing the material from oxygen−rich environment of aerobic decay; 2) Introducing the fossil to the sedimentary rock record (a.k.a., burial); and 3) "Fixing" the organic material to retard anaerobic decay, oxidation or other physical or chemical agents of destruction. Consequently, fossils are generally preserved in environments very low in oxygen (e.g., anaerobic sediment) because most decomposers (e.g., fungi, most decomposing bacteria and invertebrates) require oxygen for metabolism. Such sediments are commonly gray, green or black rather than red, a sedimentary signal of oxygen−rich conditions. The "fixing" requirement means that organism must fall into an environment rich in humic acids or clay minerals, which can retard decay by blocking the chemical sites onto which decomposers fasten their degrading enzymes. Plant material or bone can also be "fixed" by removing degradable organic compounds during the process of charring by wildfire. This is a common and spectacular mode of preservation for flowers. For mineral shells of many marine invertebrates, "fixation" may be as simple as the natural inversion of aragonite to calcite. Thus, burial may be the only key to the preservation of mineral shells. Furthermore, acid environments may actually harm both bone and shell because natural acids tend to dissolve the mineral carbonates. This creates the interesting but frustrating observation that fossil plants (which require acid conditions for preservation) and fossil vertebrates (which require basic conditions) are almost never found together. Fossils can be incorporated into the rock record in areas where sediment is being deposited, which usually, but not always, requires the presence of water. Consequently, streams, flood plains, lakes, swamps, and the ocean are good candidates for fossil−forming systems. Blowing (eolian) sand may bury vertebrates allowing good preservation, but this medium tends not to lock out enough oxygen to preserve organic material well.

Gondwana flora

The most important fossil flora of India is what is known as the Gondwana Flora which covers the period Upper Carboniferous to Jurassic. Indian plant fossils are known before (a few) and after (quite a large number) this period but no flora is as interesting as the Gondwana Flora. Towards the end of the Palaeozoic were the great Hercynian mountain building waves.

This was followed in the Upper Carboniferous and the Permian by severe glaciation and the Permian in India is the greatest coal- forming age. The geography of the Earth at that time was quite different from what it is today.

There were three continents—the Eur-American Continent (modern Europe and North America) to the North-West, Angaraland (Siberia and North China) to the North-East and a vast Gondwana land on the South which combined the land masses of India, Africa, Australia, South America and Antarctica. In between the continents was the great Sea of Tethys.

The Gondwana land has been named after the Gond tribe of Madhya Pradesh ruled by the famous Rani Durgabati during the reign of Akbar. The name was coined by H. B. Medlicott in 1872 but actually published by O. Feistmantel in 1876. The Gondwana land began to split in the Jurassic as shown by the intensive lava injections at that age.

There was drifting apart of the continents in the Cretaceous, gradually bringing them to their present positions. Another series of great mountain building waves built the present dominant Mountains (Himalayas, Alps, etc.) on the location of the Sea if Tethys.

The whole Gondwana land (now distributed over five continents) shows a uniformity of the Flora (and also the Fauna).

In Indian Geology the Gondwana rocks are considered to form a Group which is almost equivalent to an Era like Palaeozoic. Feistmantel (1882) divided the Gondwana into Lowor Gondwana (Permo-Carboni- ferous with Glossopteris Flora), Middle Gondwana (Triassic with Glossopteris-Thiimfeldia (Dicroidium Flora) and Upper Gondwana (Jurassic with Ptilophyllum Flora).

This three-fold division has been followed by many authorities like Wadia and Lele. But many other authorities prefer a two-fold division into Lower Gondwana (Upper Carboniferous to Lower Triassic) and Upper Gondwana (Lower Triassic to Jurassic, probably reaching Cretaceous).

The two-fold division is supported by the two (Glossopteris Flora and Thinnfeldia (Dicroidium)—Ptilophyllum Flora) distinct floras (and faunas) in the two divisions.

There is a sudden break between the two floras as during the Upper Permian and Triassic intensive glaciation and drought killed most of the previous early Gymnosperms and arborescent Pteridophytes giving place to the more modern Gymnosperms and herbaceous Pteridophytes (mainly ferns).

Indian Gondwana beds are named as shown in Table II. The two-fold system (i.e., only Upper and Lower Gondwana) has been followed in this book but the Middle Gondwana beds and fossils have also been pointed out.

As seen from the Table, places in Indian showing Gondwana rocks occur mainly in the Damodar, Sone, Narbada, Godavari and Mahanadi Valleys. There are also some exposure along the Himalayan foothills of Nepal, Bhutan and Arunachal and also in the Punjab, Himachal, Kashmir and Baluchistan.

Upper Gondwana rocks are more detached occurring in patches along Rajmahal-Cuttack to Kanya Kumari, in Madhya Pradesh, Rewa, Saurashtra, Kutch and in Ceylon. The Map in Figure 514 shows the principal outcrops of Gondwana rocks. It should be noted against that the Triassic beds (Maleri, Mahadeva, Pachmarhi, Parsora, Panchet) spreading from Sone to Godavari Valleys are placed by some in Middle Gondwana.

Gangamopteries

Gangamopteris is a genus of Carboniferous-Permian plants, very similar to *Glossopteris*. Previously, it was classified as fern with reproduction by seed. The genus is usually only applied to leaves, making it a form taxon. *Gangamopteris* dominates some coal deposits, such as those of the Beacon Supergroup.

In Paleorrota geopark in Rio Grande do Sul, Brazil, were found *Gangamopteris obovata*. Were located on the Mina *Morro do Papaléo* in Mariana Pimentel and *Quitéria* in Pantano Grande. Dating from the Permian and were in the Rio Bonito Formation. In the town of Cachoeira do Sul, met *Gangamopteris sulriograndensis* were discovered.

Glosspteries

. Glossopteris, genus of fossilized woody plants known from rocks that have been dated to the Permian and Triassic periods (roughly 300 to 200 million years ago), deposited on the southern supercontinent of Gondwana. *Glossopteris* occurred in a variety of growth forms. Its most common fossil is that of a tongue-shaped leaf with prominent midrib and reticulate venation. *Glossopteris* leaves are commonly found in thick mats, and thus some authorities speculate that the plants were deciduous. It reproduced by seeds, and a tremendous variety of both ovule-bearing and pollen-bearing reproductive structures are borne on characteristic *Glossopteris* leaves. Before the last of this group finally succumbed to extinction at the end of the Triassic Period, *Glossopteris* became one of the major features of the flora of Gondwana. The distribution of this plant was among the first evidence for continental drift.

Calamites

Calamites, genus of tree-sized, spore-bearing plants that lived during the Carboniferous and Permian periods (about 360 to 250 million years ago). *Calamites* had a well-defined node-internode architecture similar to modern horsetails, and its branches and leaves emerged in whorls from these nodes. Its upright stems were woody and connected by an underground runner; however, the central part of the stem was hollow, and fossils of *Calamites* are commonly preserved as casts of this hollow central portion. *Calamites* grew to 20 metres (about 66 feet) tall, standing mostly along the sandy banks of rivers, and had the ability to sprout vigorously from underground rhizomes when the upper portions of the plant were damaged. The remains of *Calamites* and other treelike plants from the Carboniferous Period were transformed into the coal used as a source of energy today. A virtually identical plant from the Triassic Period (about 250 to 200 million years ago) is called *Neocalamites*.

Lepidodendron

Lepidodendron, extinct genus of tree-sized lycopsid plants that lived during the Carboniferous Period (about 359 million to 299 million years ago). *Lepidodendron* and its relatives—*Lepidophloios*, *Bothrodendron*, and *Paralycopodites*—were related to modern club mosses. They grew up to 40 metres (130 feet) in height and 2 metres (about 7 feet) in diameter. During their juvenile stages, these plants grew as unbranched trunks with a shock of long, thin leaves that sprouted near the growing tip. They branched at later stages, either in even dichotomies at the growing tip or in lateral branches that were later shed. After branching, the leaves became shorter and awl-shaped. As the plant grew, it shed leaves from older parts of the stem that left diamond-shaped leaf bases. Stems were characterized by a slender central strand of wood and a thick bark. Since *Stigmaria*—the underground parts of the plant—resembled stems, they are not considered true roots. The shape of leaf bases and the arrangement of their vascular strands distinguish the different genera within the group of arborescent lycopsids.

Sigilaria

Sigillaria, extinct genus of tree-sized lycopsids from the Carboniferous Period (about 360 to 300 million years ago) that are related to modern club mosses. *Sigillaria* had a single or sparsely branched trunk characterized by a slender strand of wood and thick bark. Long, thin leaves grew in a spiral along the trunk but persisted only near its growing tip; on lower portions of the plant where the leaves had fallen off, characteristic polygonal leaf scars remained. *Sigillaria* reproduced by spores of two distinct sizes. The larger megaspores produced egg cells, whereas the smaller microspores produced sperm cells. *Sigillaria* appears to have preferred mineral soils of river floodplains, in contrast to its relative, *Lepidodendron*, which grew in peat-forming swamps. This preference for better-drained soils may have allowed *Sigillaria* to survive the drying of the great coal swamps that led to the extinction of many tree-sized lycopsids during the middle of the Pennsylvanian Subperiod (318 to 299 million years ago).

Ptilophyllum

The leaf is compound .It consist of a series of leafets arranged on the either either side of a coomon radials.The margin of the pinnule is entire with acute apex.The veinus of the pinnule are parallel or sub parallel to the margin .The pinnules overlap each other and they are attached to the main rachis is an oblique manner.The apex of the pinnules are always pointing upward.

Division-pterpsida,class-gymnospermae,sub class-cycadophyta order-bennettitales,genus-ptilophylum,range in time-upper gondwana,Indian horizon-rajmahal series of lower gondwana.

References

- **www.ck12.org>biology>vertebrates-evolution**
- **www.history.com>topics>dinosaurs**
- **www.nhm.ac.uk>discover>dinodirecory**
- **www.britannica.com>..>dinosaurs**
- **www.livescience.com**
- **Tera.govt,nz>foosil**
- **Ucmp.berkeiey.edu**
- **www.biology.discussion.com>india**
- **www.britannica.com>plant>fossil.**