MINEOLA BIBLE INSTITUTE

Palenontology

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PALEONTOLOGY

Paleontology, study of prehistoric animal and plant life through the analysis of fossil remains. The study of these remains enables scientists to trace the evolutionary history of extinct, as well as, living organisms. Paleontologists, also play a major role, in unraveling the mysteries of the earth's rock strata (layers). Using detailed information on how fossils are distributed in these layers of rock, paleontologists help prepare accurate geologic maps, which are essential in the search for oil, water, and minerals.

Most people did not understand the true nature of fossils until the beginning of the 19th century, when the basic principles of modern geology were established. Since about 1500, scholars had engaged in a bitter controversy over the origin of fossils. One group held the modern view that fossils are the remains of prehistoric plants and animals. This group was opposed by another, which declared that fossils were either freaks of nature or creations of the devil. During the 18th century, many people believed that all fossils were relics of the great flood, recorded in the Bible.

Fossils and Stratigraphy

Paleontologists gain most of their information by studying deposits of sedimentary rocks that formed in strata over millions of years. Most fossils are found in sedimentary rock. Paleontologists use fossils and other qualities of the rock to compare strata around the world. By comparing, they can determine whether strata developed during the same time or in the same type of environment. This helps them assemble a general picture of how the earth evolved. The study and

comparison of different strata is called, *stratigraphy*.

Fossils provide most of the data, on which, strata are compared. Some fossils, called *index fossils*, are especially useful because they have a broad geographic range, but a narrow temporal one - that is, they represent a species that was widespread, but existed for a brief period of time. The best index fossils tend to be marine creatures. These animals evolved rapidly and spread over large areas of the world. Paleontologists divide the last 570 million years of the earth's history into eras, periods, and epochs. The part of the earth's history before about 570 million years ago, is called Precambrian time, which began with the earth's birth, probably more than 4 billion years ago.

The earliest evidence of life consists of microscopic fossils of bacteria that lived as early as 3.6 billion years ago. Most Precambrian fossils are very tiny. Most species of larger animals, that lived in later Precambrian time, had soft bodies without shells or other hard body parts that would create lasting fossils. The first abundant fossils of larger animals, date from about 600 million years ago.

The Paleozoic Era

The Paleozoic era lasted about 345 million years. It includes the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian periods. Index fossils of the first half of the Paleozoic era, are those of invertebrates, such as trilobites, graptolites, and crinoids. Remains of plants and such vertebrates as fish and reptiles, make up the index fossils of the second half of this era.

Cambrian Period

At the beginning of the Cambrian period, about 570 million years ago, animal life was entirely confined to the seas. By the end of the period, all the phyla of the animal kingdom existed, except for vertebrates. The characteristic animals of the Cambrian period were the trilobites, a primitive form of anthropod, which reached their fullest development, in this period, and became extinct by the end of the Paleozoic era. The earliest snails appeared in this period, as did the cephalopod mollusks. Other groups represented, in the Cambrian period, were brachiopods, bryozoans, and foraminifers.

Plants of the Cambrian period included seaweeds, in the oceans, and lichens, on land.

Ordovician Period

The most characteristic animals of this period, which began about 500 million years ago, were the graptolites, which were small, colonial hemi-chordates (animals possessing an anatomical structure suggestive of a portion of a spinal cord). The first vertebrates - primitive fish - and the earliest corals emerged during the Ordovician period. The largest animal of this period, was a cephalopod mollusk, that had a shell about 3 m (about 10 ft.) in length. Plants, of this period, resembled those of the Cambrian period.

Silurian Period

The most important evolutionary development of this period, which began about 430 million years ago, was that of the first air-breathing animal, a scorpion. Fossils of this creature have

been found in Scandinavia and Great Britain. The first fossil records of vascular plants - that is, land plants with tissue that carries food - appeared in the Siluriana period. They were simple plants that had not developed separate stems and leaves.

Devonian Period

The dominant forms of animal life, in this period, which began about 395 million years ago, were fish of various types, including sharks, lungfish, armored fish, and primitive forms of ganoid (hard-scaled) fish, that were probably, the evolutionary ancestors of amphibians. Fossil remains found in Pennsylvania and Greenland, indicate that early forms of amphibia, may already have existed, during the Devonian period. Early animal forms included corals, starfish, sponges, and trilobites. The earliest known insect was found in Devonian rock.

The Devonian is the first period, from which, any considerable number of fossilized plants have been preserved. During this period, the first woody plants developed, and by the end of the period, land-growing forms included seed ferns, ferns, scouring rushes, and scale trees, the modern relative of club moss. Although the present-day equivalents of these groups are mostly small plants, they developed into tree-like forms, in the Devonian period. Fossil evidence indicates, that forests existed, in Devonian times, and petrified stumps of some of the larger plants, from the period, measure about 60 cm (about 24 in.) in diameter.

Carboniferous Period

The Carboniferous period began about 345 million years ago. During the first part of this period, sometimes called the

Mississippian period, the seas contained a variety of echinoderms and foraminifers, as well as most forms of animal life, that appeared in the Devonian. A group of sharks, the Cestraciontes - or shell-crushers - were dominant among the larger marine animals. The predominant group of land animals was the Stegocephalia, an order of primitive, lizard-like amphibians, that developed from the lungfish. The various forms of land plants became diversified and grew larger, particularly those, that grew in low-lying swampy areas.

The second part of the Carboniferous, sometimes called the Pennsylvania period, saw the evolution of the first reptiles, a group that developed from the amphibians and lived entirely, on land. Other land animals included spiders, snails, scorpions, more than 800 species of cockroaches, and the largest insect ever evolved, a species resembling the dragonfly, with a wingspread of about 74 cm (about 29 in.). The largest plants were the scale trees, which had tapered trunks that measured as much as 1.8 m (6 ft.) in diameter, at the base, and 30 m (100 ft.), in height. Primitive gymnosperms, known as cordaites, which had pithy stems, surrounded by a woody shell, were more slender, but even taller. The first true conifers, forms of advanced gymnosperms, also developed during the Pennsylvanian period.

Permian Period

The chief events of the Permian period, which began about 280 million years ago, were the disappearance of many forms of marine animals and the rapid spread and evolution of the reptiles. In general, Permian reptiles were of two types: lizard-like reptiles that lived entirely on land, and sluggish, semi-aquatic types. A comparatively small group of reptiles that evolved, in this period, the *Theriodontia*, were the

ancestors of mammals. Most vegetation of the Permian period was composed of ferns and conifers.

The Mesozoic Era

The Mesozoic era, is often called, the Age of Reptiles, because the reptile class was dominant on land, throughout the entire age. The Mesozoic era, lasted about 160 million years, and includes the Triassic, Jurassic, and Cretaceous periods. Index fossils, from this era, include a group of extinct cephalopods called ammonites, and extinct forms of sand dollars and sea urchins.

Triassic Period

The most notable of the Mesozoic reptiles, the dinosaur, first evolved in the Triassic period, which began about 225 million years ago. The Triassic dinosaurs were not as large as their descendants, in later Mesozoic times. They were comparatively slender animals, that ran on their hind feet, balancing their bodies with heavy, fleshy tails, and seldom exceeded 4.5 m (15 ft.), in length. Other reptiles of the Triassic period included such aquatic creatures, as the ichthyosaurs, and a group of flying reptiles, the pterosaurs.

The first mammals, also appeared, during this period. The fossil remains of these animals are fragmentary, but the animals, were apparently, small in size, and reptilian, in appearance. In the sea, Teleostei, the first ancestors of the modern bony fishes, made their appearance. The plant life of the Triassic seas, included a large variety of marine algae. On land, the dominant vegetation, included various evergreens, such as ginkgos, conifers, and palms.

Jurassic Period

During the Jurassic period, which began about 195 million years ago, dinosaurs continued to evolve in a wide range of size and diversity. Types included, heavy four-footed sauropods, such as *Apatosaurus* (formerly *Brontosaurus*); two-footed carnivorous dinosaurs, such as *Tyrannosaurus Rex;* two-footed vegetarian dinosaurs, such as *Trachodon;* and four footed armored dinosaurs, such as *Stegosaurus*. Winged reptiles included, the pterodactyl, which, during this period, ranged in size, from extremely small species, to those with wingspreads of 1.2 m (4 ft.). Marine reptiles included plesiosaurs, a group that had broad, flat bodies, like those of turtles, with long necks and large flippers for swimming; Ichthyosauria, which resembled dolphins; and primitive crocodiles.

The mammals of the Jurassic period, consisted of four orders, all of which, were smaller than small modern dogs. Many insects of the modern orders, including moths, flies, beetles, grasshoppers, and termites appeared during the Jurassic period. Shellfish included lobsters, shrimp, and ammonites, as well as, the extinct group of belemnites, which resembled squid and had cigar-shaped internal shells. Plant life, of the Jurassic period, was dominated by the cycads, which resembled thick-stemmed palms. Fossils of most species of Jurassic plants, are widely distributed, in temperate zones and polar regions, indicating that the climate, was uniformly, mild.

Cretaceous Period

The reptiles were still the dominant form of animal life in the Cretaceous period, which began about 136 million years ago. The four types of dinosaurs, found in the Jurassic, also lived during this period, and a fifth type, the horned dinosaurs, also

appeared. By the end of the Cretaceous, about 65 million years ago, all of these creatures had become extinct. The largest of the pterodactyls, lived during this period. Pterodactyl fossils, discovered in Texas, have wingspreads of up to 15.5 m (50 ft.). Other reptiles, of this period, include the first snakes and lizards. Several types of Cretaceous birds have been discovered including, *Hesperomis*, a diving bird about 1.8 m (about 6 ft.) in length, which had only vestigial wings and was unable to fly. Mammals of the period, included the first marsupials, which strongly resembled the modern opossum, and the first placental mammals, which belonged to the group of insectivores. The first crabs developed, during this period, and several modern varieties of fish, also evolved.

The most important evolutionary advance, in the plant kingdom during the Cretaceous period, was the development of deciduous plants, the earliest fossils, of which, appear in early Cretaceous rock formations. Fig, magnolia, sassafras, and poplar were among the first to evolve. By the end of the period, many of the modern varieties of trees and shrubs had made their appearance. They represented more than 90 percent of the known plants of the period. Mid-Cretaceous fossils include remains of beech, holly, laurel, maple, oak, plane tree, and walnut. Some paleontologists believe that these deciduous woody plants, first evolved in Jurassic times, but grew only in upland areas, where conditions were unfavorable for fossil preservation.

The Cenozoic Era

The Cenozoic era began about 65 million years ago. It is divided into the Tertiary period and the Quaternary period, which includes modern times. However, because scientists have so much more information about this era, they tend to

focus on the epochs, that make up each period. During the first part of the Cenozoic era, an abrupt transition from the Age of Reptiles to the Age of Mammals occurred, when the large dinosaurs and other reptiles that had dominated the life of the Mesozoic era disappeared.

Index fossils of the Cenozoic, tend to be microscopic, such as the tiny shells of foraminera. They are commonly used, along with varieties of pollen fossils, to date the different rock strata of the Cenozoic era.

Paleocene Epoch

The Paleocene epoch marks the beginning of the Cenozoic era. Seven groups of Paleocene mammals are known. All of them appear to have developed in northern Asia and to have migrated to other parts of the world. These primitive mammals had many features in common. They were small, with no species exceeding the size of a small modern bear. They were four-footed, with five toes on each foot, and they walked on the soles of their feet. Almost, all of them, had slim heads with narrow muzzles and small brain cavities. The predominant mammals of the period, were members of three groups, that are now extinct. They were the *creodonts*, which were the ancestors of modern carnivores; the *amblypods*, which were small, heavy-bodied animals; and the *condylarths*, which were light-bodied herbivorous animals, with small brains. The Paleocene groups, that have survived, are the marsupials, the insectivores, the primates, and the rodents.

Eocene Epoch

During the Eocene epoch, which began about 54 million years ago, a number of direct evolutionary ancestors of modern

animals appeared. Among these animals - all of which, were small in stature - were the horse, rhinoceros, camel, rodent, and monkey. The creodonts and ambly-pods continued to develop during the epoch, but the condylarths became extinct before it ended. The first aquatic mammals, ancestors of modern whales, also appeared in Eocene times, as did such modern birds as eagles, pelicans, quail, and vultures. Changes in vegetation, during the Eocene epoch, were limited chiefly, to the migration of types of plants, in response, to climate changes.

Oligocene Epoch

During this epoch, which began about 38 million years ago, most of the archaic mammals from earlier epochs of the Cenozoic era, disappeared. In their place appeared representatives of a large number of modern mammalian groups. The creodonts became extinct, and the first true carnivores, resembling dogs and cats, evolved. The first anthropoid apes, also lived during this time, but they became extinct in North America, by the end of the epoch. Two groups of animals, that are now extinct, flourished during the Oligocene epoch: the *titanotheres,* which are related to the rhinoceros and the horse; and the *creodonts,* which are related to the rhinoceros and the horse; and the *oreodonts*, which were small, dog-like, grazing animals.

Miocene Epoch

The development of mammals, during the Miocene epoch, which began about 26 million years ago, was influenced by an important evolutionary development in the plant kingdom: the first appearance of grasses.

These plants, which were ideally suited for forage, encouraged

the growth and development of grazing animals, such as horses, camels, and rhinoceroses, which were abundant during the epoch. During the Miocene epoch, the mastodon evolved, and in Europe and Asia, a gorilla-like ape, *Dryopithecus*, was common.

Various types of carnivores, including cats and wolf-like dogs, ranged over many parts of the world.

Pliocene and Pleistocene Epochs

The paleontology of the Pilocene epoch, which began about 12 million years ago, does not differ much from that of the Miocene, although the period, is regarded by many zoologists, as the climax of the Age of Mammals. The Pleistocene epoch, in both Europe and North America, which began about 2.5 million years ago, was marked by an abundance of large mammals, most of which, were basically modern in type. Among them were buffalo, elephants, mammoths, and mastodons. Mammoths and mastodons became extinct before the end of the epoch. In Europe, antelope, lions, and hippopotamuses, also appeared. Carnivores included badgers, foxes, lynx, otters, pumas, and skunks, as well as now-extinct species, such as the giant saber-toothed tiger. In North America, the first bears made their appearance, as migrants from Asia. The armadillo and ground sloth, migrated from South America to North America, and the musk-ox ranged southward from the Artic regions. Modern human beings also emerged, during this epoch.

Aepyornis, (Greek, “tall bird”), genus of several FOSSIL birds from the island of Madagascar, especially the elephant bird. This great BIRD, may have survived, until the arrival of the first humans on Madagascar, and thus, given rise to the legend of

the roc, the gigantic mythical bird, once believed to have inhabited INDIA, and later, popularized in the *Arabian Nights.*

The adult elephant bird was about 2.4 to 2.7 m (about 8 to 9 ft.) tall and extremely massive, weighing perhaps, as much as 450 kg (about 1,000 lb.), by far, the heaviest of any known bird. Several of its eggs have been found, fossilized in the mud of swamps.

Albertosaurus, formerly known as *Gorgosaurus*, genus of carnivorous DINOSAUR that lived in Alberta and Montana in the Late Cretaceous period, from about 100 million years ago, to the time of the extinction of the dinosaurs, about 65 million years ago. Not quite as large as the related *Tyrannosaurus rex*, the bipedal *Albertosaurus*, had a similar appearance and weighed up to about 3 tons.

Allosaurus, genus of large, carnivorous dinosaurs, of the sub-order Theropoda, that flourished approximately, 150 million years ago, during the Late Jurassic period. These saurischian (lizard-hipped) dinosaurs reached 12 m (40 ft.) in length, stood more than 4.5 m (15 ft.) tall, and weighed up to 3.6 metric tons. Like other members of the sub-order, Theropoda, *Allosaurus* was an obligatory biped; it walked on stout hindlegs with large bird-like feet, while using its heavy tail for balance. The digits of the feet and the hands of the shorter forelimbs were equipped with sharp, grasping claws. The jaws of its huge head (1 m/3 ft. long) were filled with long, serrated teeth, that enabled *Allosaurus* to bolt enormous chunks of flesh. Fossil remains of *Allosaurus*, have been found in Wyoming and Colorado.

Ammonite, common name for an extinct group of

cephalopods, that usually had a tightly coiled, spiral-shaped shell. These squid-like animals appeared during the Devonian period, approximately 380 million years ago and died out along with the dinosaurs, at the end of the Cretaceous period, 65 million years ago. The shell of the ammonite, was chambered, like that of its still-living relative, the nautilus. The predominantly gas-filled, chambered part of the shell, called the *phragmocone,* was partitioned by a series of closely, spaced plates called, *septa*. The animal lived in the last chamber; this chamber occupied anywhere from less than a whorl, to a full, one-and-a-half whorls, of the shell. Some kinds of ammonites, however, did not have a tightly-coiled shell; *Baculites*, for example, had a straight shell.

Ammonites abounded in shallow marine environments on the edges of continents, although they were rather, slow swimmers and avoided extremely shallow wave-dominated waters, close to shore. Ammonites, also thrived, in continental seas, like those which covered the interior of North America, during the Late Cretaceous period, and in the ancient Tethys Sea, that once covered southern Europe, northern Africa, and parts of Asia. In the Tethys Sea, during the Jurassic and Cretaceous periods, the genera, *Lytoceras and Phylloceras*, were especially numerous.

Ammonites have played an important role in the development of *zonations*, or time scales, for the marine environment. Comparing the types of ammonite fossils, in rock layers, indicates the relative ages of the rock.

Ankylosaurae, family of plant-eating DINOSAURS, found worldwide, during the later Cretaceous period, which ended

about 65 million years ago. The heavily armored ankylosaurs were medium-sized, *omithischian* (bird-hipped) dinosaurs that ranged from 4.5 to 10 m (15 to 33 ft.) long. They moved on all fours, and their broad, low bodies were covered with rows of bony plates, which ended in a club-like tail. Some species had spines on the head, along the back, or on the tail. They were related to the stegosaurs, another type of armored dinosaur, that lived earlier. The slow-moving ankylosaurs, probably resembled armadillos, and their fossils, usually occur, in regions that were once swampy.

Apatosaurus, (formerly known as *Brontosaurus*), huge, plant-eating DINOSAUR, sub-order Sauropoda, that lived in the Late Jurassic period, more than 140 million years ago. The *Apatosaurus* attained a length of about 24 m (about 80 ft.) and weighed up to 30 metric tons. Its body, was relatively, short and thick, the neck - long and slender, the tail - large and strong, and the four limbs - massive and of nearly, equal length.

The first *Apatosaurus*, skeleton was discovered, in Colorado, in 1879, by American paleontologist, Othniel Charles Marsh. It lacked a skull, so Marsh, gave it a blunt, small skull, found a few kilometers, distant. This paring remained in effect, until 1979, when scientists confirmed, that the skull was that of another sauropod, *Camarasaurus*. The *Apatosaurus's* true skull, was found to have a longer snout and longer, finer teeth.

Archaeopteryx, the first known bird, the remains, of which, were found in the 19th century, in lithographic stone (a limestone of the JURASSIC PERIOD), in Solnhofen, Bavaria, Germany. To date, six FOSSIL specimens, have been found. The bird appears to have ranged

from the size of a pigeon, to that, of a small crow. It had many characteristics of dinosaurs. The vertebral column was extended, so as to form, a long tail, and quilled feathers grew, from each vertebra. The entire body was covered with feathers. A striking intermediate between later birds and other small Mesozoic carnivorous dinosaurs, *Archaeopteryx*, is one of the best examples of evolution.

Brachiosaurus, genus of large dinosaurs, of the sub-order Sauropoda, that flourished, during the Late JURASSIC PERIOD. Its forelegs, were slightly longer, than its hind legs. *Brachiosaurus*, was about 24 m (about 80 ft.) long, weighed about 80 metric tons, and was about 12.6 m (43 ft.) tall, at the head. Fossil remains, of the animal, have been found in the western United States, as well as, in eastern Africa. *Brachiosaurus*, according to recent research, was a land dweller, that probably fed, on tall foliage.

Compsognathus, genus of tiny, carnivorous, bird-like dinosaurs, that lived during the Late Jurassic period. *Compsognathus* was about 60 cm (2 ft.) long and weighed, a little more than, 3 kg (6.5 lb.). It had remarkably bird-like legs and feet; the shorter forelimbs ended in delicate hands, with three grasping digits. The jaws, of its small-pointed head, contained many sharp teeth. The bipedal, *Compsognathus*, used its long, slender tail for balance, as it ran after prey, which probably included, insects and small lizards and mammals. Two specimens of *Compsognathus* have been found, one in 1861, in the same sequence of limestone layers, in southern Germany, that contained *Archaeopteryx*, and one in the south of France, in 1978.

Conodont, form of microfossil, commonly found, in marine

limestones, dating from the Cambrian period to the TRIASSIC PERIOD, from about 570 million to about 210 million years ago. Conodonts are sturdy fossils, that consist of the calcium phosphate mineral, called apatite. With more than 1,000 different forms known, these fossils have been of great use to geologists, in correlating rock strata, around the world. As their name implies, many conodonts are basically, cone-shaped, but others are shaped like, bars or blades. Conodonts are very small; the largest conodonts found, are only about 6 mm (about 0.24 in.) long.

Conodont fossils are the remains of the hard parts, such as a shell or teeth, of animals that evolved, in ancient seas. Remains of the animals, that give rise to conodont fossils, have only recently, been discovered. This animal is a small, worm-like invertebrate; whether or not it is related to any type of organism, living today, is unclear.

Deinonychus (Greek *deinos*, "terrible;" *onychos*, "claw"), genus of small, bipedal, flesh-eating dinosaurs, of the sub-order Theropoda, that lived during the Early Cretaceous period, which began about 136 million years ago. Fully grown, this fierce theropod stood as high as 1.5 m (5 ft.), measured 2.75 m (9 ft.) in length, and weighed up to 80 kg (175 lb.). *Deinonychus* was a strong runner and carried its body, horizontally, on long, robust hind legs with its tail, rigidly stretched out behind, for balance, as it attacked its prey. The jaws, of its relatively large head, were equipped with large, serrated teeth. The three toes, of the forelimbs, were armed with long, re-curved claws, one of which, earned the animal its name: the second toe, bore a 13 cm (5 in.) sickle-shaped, retractable claw, that must have been, a formidable offensive weapon. *Deinonychus*, is known, from fossil remains, found in

Montana.

Dimetrodon, genus of predatory pelycosaur, a mammal-like reptile, that flourished in North America, in the early Permian period, which began about 280 million years ago. Fossil remains of the long-tailed, sail-backed, *Dimetrodon* range up to 3.5 m (11.5 ft.), in length, and are distinguished by a large, dorsal sail, or fin. This sail, the supporting spines, of which, were formed from the dorsal vertebrae, was a membrane, rich in blood vessels, and may have served, to regulate the animal's body temperature. *Dimetrodon*, may have exercised, fine control over the gain or loss of body heat, by carefully positioning the sail, with respect to sun, shade, and wind.

Dinosaur, any member of a group of about 350 well-known genera of archosaurian reptiles, that first appeared, in the late Middle or early Late Triassic Period, about 200 million years ago. Dinosaurs comprise two orders: the "bird-hipped" Ornithischia and the "reptile-hipped" Saurischia. The earliest known dinosaurs, such as *Staurikosaurus and Herrerasaurus*, from South America, are too primitive, to be classified within either order. Eoraptor, another very primitive dinosaur, discovered in 1992, has been tentatively classified, as a member of the order, Saurischia.

Dinosaurs, arose at a time, when the land was dominated by crocodile-like phytosaurs, giant amphibians, archosaurian carnivores, and large therapsids. The first dinosaurs were small, lightly built, bipedal carnivores or omnivores, that were probably, quicker and more agile, than their contemporaries, most of which, became extinct, by the end of the Triassic Period. During the Jurassic

Period and Cretaceous Period, the dinosaurs evolved into myriad adaptive types, many of which, reached colossal size.

Remains of dinosaurs, were first discovered, in England, in the 1820's. By the 1840's, several genera, were well-enough known, that the great comparative anatomist, Richard Owen, gave them the name, Dinosauria. In doing so, he recognized the uniqueness of their great size, their terrestrial habits, their upright posture, and the inclusion, of at least five vertebrae, in their hip girdles. It was not until the exploration of the western United States, in the 1880's however, and the recovery of complete dinosaur skeletons, from the badlands, that dinosaurs were recognized, as having been largely bipedal - a most unusual stance for a reptile, and one that led to much speculation about their locomotion, behavior, and physiology.

In the 1880's, H. G. Seeley, saw that Dinosauria could be divided into two orders, based on the form of the hip girdle. The Ornithischia, had pubic bones that, like those of birds, faced posteriorly. The more conventional Saurischia, had pubic bones, that faced anteriorly. Ironically, it was the reptile-hipped, Saurischia, from which, birds evolved, specifically from small carnivorous dinosaurs, related to *Deinonychus* and *Compsognathus*. The reversal of the pubis, was an evolutionary convergence in birds and ornithischians.

Dinosaurs are distinguished by an erect posture, in which, the limbs are brought, more or less, under the body, in the fashion of birds and mammals, rather than, sprawling to the side, as in crocodiles, lizards, and turtles. They share this characteristic with pterosaurs, their closest relatives, as well as with their descendants, the birds. Their footprints, show

that, the bipedal dinosaurs, walked as birds do, putting one foot in front of the other, toed slightly inward. Their hands were prehensile, with thumbs somewhat opposable, to the other digits. Their brains, were generally, larger than average for reptiles, particularly, in the carnivores and duck-billed dinosaurs.

Ornithischian Dinosaurs

The earliest ornithischians, include the poorly known Triassic form, *Pisanosaurus*, from South America and Early Jurassic genera such as, *Heterodontosaurus* and *Scutellosaurus*. One lineage, known collectively as, Thyreophora, includes the plated, *Stegosaurus* and the armored Ankylosaurae, and ranges from the Early Jurassic through the Late Cretaceous. A second group, the Ornithopoda, includes the duck-billed *Hadrosaurus* and their relatives the *Iguanodon*, as well as, the horned ceratopsians and their relatives, the pachycephalosaurs. The Ornithopoda, also ranged from the Early Jurassic through the Late Cretaceous.

Ornithischian dinosaurs are distinguished by their bird-like hip girdles, and also, by the presence of a predentary bone on the tip of the lower jaw. All ornithischians were herbivorous, and the predentary, appears to have served as a beak, by which, to crop vegetation, much in the manner of camels and horses. It also connected, the two halves of the lower jaws and enabled them to transmit and absorb force, during chewing. In duck-billed dinosaurs and ceratopsians, the jaws held dozens of teeth, tightly arranged, to form a single beveled battery, of chewing surface. As in all other vertebrates, except mammals, the teeth were continually replaced through life, as the roots were absorbed and new crowns developed.

Saurischian Dinosaurs

The order, Saurischia, includes two major sub-orders: (1) the herbivo-

rous Sauropodomorpha, which comprise the giant, long-necked Sauropoda, such as *Diplodocus and Apatosaurus*, as well as, the less well known, Prosauropoda, which include *Plateosaurus*; and (2) the carnivorous Theropoda, which comprise all the meat-eaters, from the smaller *Coelophysis*, *Compsognathus*, and *Deinonychus* to the great meat-eaters, such as *Allosaurus* and *Tyrannosaurus*, as well as, their descendants, the birds. Larger, bulkier sauropods, called Supersaurus and Ultrasaurus, which some experts think, may be *Brachiosaurus* or *Diplodocus*, have been found, in Colorado.

Saurischians have long necks and large claws on the first digits on their hands and feet. The fourth and fifth fingers, of the hand, are reduced or absent (as in birds, which retain, only the first three digits). The sauropods became very large and quadrupedal and evolved various adaptations, for feeding on high vegetation. In *Diplodocus*, for example, the neck and tail are both very long; the lower (haemal) arches of the tail vertebrae, at the point where the tail would normally reach them, are canoe-shaped, instead of tongue-shaped and appear to have assisted the animal in using the tail as a prop, as it fed on high vegetation, with its forelimbs raised off the ground. In *Brachiosaurus*, the neck is very long, but the tail is short; however, *Brachiosaurus*, had long forelimbs that, in combination with its long neck, enabled it to reach high vegetation, by different means, than *Diplodocus* used.

Large carnivorous theropods, such as *Tyrannosaurus*, had very large heads with great jaws filled with re-curved, doubly

serrated teeth. Their forelimbs were reduced, but their hips and hind limbs were massive, and clearly the predator, had little to do, beyond grasping its prey in its jaws, planting its feet, and tearing the flesh, until the prey suffered massive shock and blood loss. Small theropods, such as *Deinonychus*, must have been much more agile, persistent hunters, that chased down prey and attacked, in packs, ripping with teeth and claws. However, some lineages of small theropods, such as *Struthiomimus* and its relatives, were toothless, as were all, but the first birds, and they may have been more omnivorous in their habits.

Warm-Bloodedness

It is uncertain whether the dinosaurs were warm-blooded. Like birds and mammals, dinosaurs had rapid rates of growth, and their bones show evidence of secondary re-working (Haversian canal systems). They could not sprawl, like most living reptiles, and their obligate erect posture, implies continual expense of metabolic energy. Their footprints and long limbs, show that they were capable of high speeds. Probably, no single thermal-regulation mechanism, can be applied to all dinosaurs. Mammals such as bats, cats, elephants, and whales control their body temperature in different ways, and the thermal-regulation mechanisms of dinosaurs, were probably, equally varied.

Extinction

Dozens of explanations for dinosaurian extinction, have been offered, most of them, fanciful or outside the resolution of evidence. Until recently, dinosaurs were considered to have died-off gradually, through the Late Cretaceous. However, the recent discovery at the Cretaceous-Tertiary boundary, of the rare element, iridium, and of shocked quartz granules, both

signatures of the impact of a large asteroid or comet, fueled speculation, that such an impact, could have triggered climatic catastrophes, that ended the dinosaur's reign. A possible site of impact has been discovered, on the Yucatan Peninsula, in Mexico, where scientists have found, a crater, that measures about 200 km (120 mi.) in diameter. Other theories suggest that this impact was ac-companied, by widespread volcanic eruptions, or by a cloud of sulfuric dioxide, that exacerbated the destruction. Although such events, which are known to be common in geologic history, might have had some environmental consequences, the vast majority of dinosaurs, were long extinct, by that time. Moreover, the other organisms, such as crocodiles, turtles, fishes, birds, and amphibians, which might have been expected to suffer equally, from such a cataclysm, survived with only minor losses - a fact, that has yet to be explained, by any catastrophe hypothesis. It is known, that through the Late Cretaceous, the climate was becoming more unstable and seasonal, and waves of extinctions had long been affecting, both marine and terrestrial life. Although the effects of an impact, by an asteroid or comet, cannot be ruled out, they do little to explain the observed evidence of extinction and survival, at the end of Cretaceous.

Diplodocus, genus of dinosaurs of the sub-order Sauropoda. One of the largest of the dinosaurs, it lived during the Jurassic period, inhabiting the western part, of what is now, the United States. Fossil specimens indicate, that the reptile attained lengths of up to 26.5 m (87 ft.). It was relatively slender, however, and somewhat less bulky, than the related *Apatosaurus*. *Diplodocus*, was a quadruped, with a long neck, a low body, and a long tail. A vegetarian, it had a small head, with slender teeth, and probably grazed, in marshes and

shallow water.

Eoraptor, small, dog-sized dinosaur or close relative of the dinosaurs, that lived during the late TRIASSIC PERIOD, about 225 million years ago. An *Eoraptor* skull and skeleton about 1 m (about 3 ft.) long, were dis-covered, in northwestern Argentina, in 1992. They indicate, that *Eoraptor* had sharp teeth, three-fingered hands, a bipedal stance, and three-toed feet. These attributes suggest that *Eoraptor* might have been an early member of the sub-order, Theropoda, which includes all meat-eating dinosaurs. Other attributes, however, suggest, that *Eoraptor* was more primitive, and might have been, close to the common ancestor of dinosaurs. If further study shows, that *Eoraptor* is not of the Ornithischia or Saurischia orders, then it would not be a true dinosaur, but a very close relative.

Hadrosaurus, genus of dinosaur in the sub-order Ornithopoda. Their fossilized remains are in Cretaceous rocks of New Jersey and Wyoming. These large dinosaurs, which reached about 11 m (35 ft.) in length, were characterized by a flattened bill, resembling that of a duck, with which, they grasped the marsh grass and other vegetation that constituted their food. The bill, unlike that of a duck, contained many small teeth. Their hides were thick, but not covered by armor. Their heads were large, and their tails were thick and heavy. The hadrosaurs moved about swampy pools on their thick, three-toed hind limbs. Many hadrosaurs had elaborate bony crests on their skull.

Hesperornis, genus of primitive flightless birds, that lived at the end of the age of dinosaurs, about 70 million years ago. From the tip of its long, pointed bill, which contained teeth, to the end of its tail, the bird measured about 1.8 m (about 6

ft.). Its strong legs were adapted for swimming, but its forelimbs were reduced to small, non-functional wings. The best fossils come from deposits of the shallow seas, that in Cretaceous times, covered the region, that is now Kansas.

Ichthyosauria, order of marine reptiles, that lived from the early Triassic period, which began, about 240 million years ago, to the mid-Cretaceous period, which ended about 65 million years ago. There were several different species of Ichthyosauria, and they ranged, in length, from 1 to 15 m (3 to 49 ft).

The ichthyosaurs were similar, in appearance, to dolphins, with long, pointed snouts and stream-lined bodies. They had conical teeth and large eyes. Ichthyosaurs propelled themselves through the water with vertical tails, and they had flippers that consisted of limb bones, that had fused together. They gave birth to live young, which enabled them, to live entirely, in the water. Other reptiles of the time - including the dinosaurs - laid eggs on land. Ichthyosaurs, probably lived, on a diet of fish.

Iguanodon, genus of large, herbivorous dinosaurs, of the sub-order Ornithopoda, that lived worldwide, during the Early CRETACEOUS PERIOD. IGUANODON weighed as much as 4.5 metric tons, attained a length of 7.5 m (25 ft.), and stood up to 4.5 m (15 ft.) tall, on stout hind legs. The three toes of the feet and four of the five digits of the shorter forelimbs, were equipped with flat, hoof-like claws; the hand's first digit, a bony, spike-shaped thumb, situated at a right angle to the other fingers, may have been used for defense. IGUANODON'S long, flat head ended in a horny beak, and its jaws contained teeth, that somewhat resemble, those of the iguana lizard -

hence, the name. These animals may have browsed, in packs, and probably assumed, a four-legged stance, while eating.

Lepidodendron, genus of extinct trees, related to present-day club, mosses. *Lepidodendron*, were abundant, during the late PALEOZOIC era. The trees grew from 23 to 40 m (75 to 100 ft.) high and had stout, woody trunks. Lozenge-shaped leaf scars, were arrayed in rows, that spiraled around the trunk. The thin branches bore un-stalked, slender leaves and had twisted cones at the tips. The oldest remains of the genus, were discovered in rock strata, from the Devonian period, which began about 400 million years ago. During the Carboniferous period, from about 360 million years ago, the genus was abundant in swamp regions, that have become the great coal-mining areas of the northern hemisphere. Much of the vegetable matter, from which, coal developed, was composed of trunks, leaves, and cones of *Lepidodendron*.

Lungfish, common name for members of a small group of primitive, air-breathing fishes. This group, was dominant and widespread, during the Paleozoic era, and earliest fossils, belong to the Devonian period.

Three living genera of lungfishes are known. They occur in freshwater areas of eastern Australia, southwestern Africa, and northeastern South America. The name, *lungfish*, is derived from the specialized lung, that is the fishes' primary organ, for respiration. The African and American lungfishes, must rise to the surface, to breathe; the Australian lungfish can obtain sufficient oxygen, from the water, unless conditions become stagnant. The young of African and American lungfishes, have true external gills, but these degenerate, with

age. Lungfishes are brown and mottled in color and have eel-like bodies, usually from 61 cm to 1 m (24 in. to 4 ft.) in length, although some species are 2 m (6 ft.) long. The western African lungfish, is known to *estivate* (become dormant) during dry periods, usually for only a few months, but possibly for more than four years. The fish burrows into the mud and secretes a mucous covering around itself. The mucus hardens, leaving a small closable breathing vent. This "cocoon" softens, when wet, as at the end of the dry season, and the fish can then, re-emerge and live in the water again.

Scientific classification: Lungfishes make up the sub-class, Dipnoi of the class, Osteichthyes. The Australian lungfish is classified as *Neoceratodus forsteri*, and the South American lungfish as, *Lepidosiren paradoxa*. African lungfishes are classified in the genus, *Protopterus*.

Mammoth, common name for several extinct species of the elephant family. Mammoths had long, re-curved tusks, reaching a length of about 3.2 m (about 10.5 ft.), a shaggy covering of long, thick hair, and a prominent hump on the back. They lived in cold climates, moving north-ward, as the glaciers, of the Ice Age, receded. They existed in North America, Europe, and Asia, during the Pleistocene epoch. Drawings and sculpture, depicting mammoths, have been found, in the Cro-Magnon caves, of France. In northern Siberia, complete mammoths have been found, preserved in ice - sometimes to the degree, that tiny amounts of DNA have been recovered. The American mammoth, *Mammuthus imperator*, is the largest species, as yet, identified; it reached a height of about 4.3 m (about 14 ft.). The woolly mammoth, *M. primigenius,* of Siberia, was about the size of the modern Indian elephant; a complete specimen of this animal, was first

disinterred, near the mouth of the Lena River, in Siberia, in 1806.

Mastodon, common name for any of the extinct elephant-like mammals, that constituted the family, Mastodontidae of the order, Proboscides ("long-snouted"). The leaf-eating mastodons, were widely distributed, in the forests of the world, from Oligocene to Pleistocene times. Their remains, have been found, worldwide, and are often, remarkably well-pre-served. Like the modern elephant, the mastodon was very large, with thick, sturdy legs; a huge head; tusks; and a flexible, muscular trunk. Like the MAMMOTH, the mastodon was covered with shaggy hair. The animals differed from elephants and mammoths, however, in having complete tuberculate teeth. Their upper tusks were long and curved; they had transverse crests on their grinding teeth. *Mastodon americanus*, almost the size of a modern Indian elephant was common, throughout what is now, the United States; it did not become extinct, until about 8,000 years ago.

Perissodactyl, any member of the three families of hoofed mammals - the horses, tapirs, and rhinoceroses. The term is derived from Greek words, meaning "odd-toed," as contrasted with the artiodactyls order, of even-toed hoofed mammals. Members of the horse family, have only one toe on each foot; those of the rhinoceros family, have three functional toes, on both front and hind feet, and those of the tapir family, have four toes, on the front feet and three on the hind feet.

The 17 perissodactyl species, living today, are only a remnant of the many forms, that once roamed the earth. They first appeared, early in the EOCENE EPOCH, about 55 million years ago, and several gigantic forms, later developed. For example,

the North American titanothere, of the OLIGOCENE EPOCH, (40 million to 26 million years ago) stood 2.5 m (8 ft.), at the shoulder. The uninterrupted fossil record of perissodactyls, offers a clear illustration, of evolutionary processes. Consequently, paleontologists have been able to trace the horse, from a dog-size animal with four toes on the front feet, to the swift-galloping, single-toed animal, of today. The changes, in the surface structure, of early perissodactyl teeth, also illustrate, how these animals evolved, from general to specialized herbivores, that today, feed only on particular kinds of plants. Perissodactyls, are now, on the decline in the wild, perhaps because of human encroachments.

Scientific classification**:** Perissodactyls make up the order, Perisso-
dactyla. Horses belong to the family, Equidae, tapirs make up the family, Tapiridae, and rhinoceroses, make up the family, Rhinocerotidae.

Plesiosaur, any member of a group of carnivorous ocean-dwelling rep-
tiles, that flourished during the Age of Reptiles, from the LATE TRIASSIC PERIOD to the end of the CRETACEOUS PERIOD, about 65 million years ago. Some plesiosaurs were more than 12 m (10 ft.) long. Two major types of plesiosaur existed, one with a long neck, and relatively small head, and the other, with a short-neck and a large head. In some species, the large head accounted for about, one-fourth of the animal's total length. The limbs of plesiosaurs were like flippers; the tail was short.

Pterosaur, (Greek *ptero*, "wing;" *sauros,* "lizard"), flying reptile, that
existed, during the Mesozoic era, from the Late Triassic

period, nearly to the end of the Cretaceous period. Many fossil remains of pterosaurs, which are often popularly referred to, as pterodactyls, have been found in all continents, except Antarctica; about 60 genera, have been discovered.

Pterosaurs, did not have feathers. The wings, were thin membranes of skin, similar to the wings of a bat, which extended along the sides of the body, and were attached to the extra-ordinarily long fourth digit, of each arm. The bones were hollow and had openings at each end. Unlike typical reptiles, pterosaurs had a breastbone, that was well-developed, for the attachment of flight muscles and a brain that was also, more developed.

In early pterosaurs of the Late Triassic period, the skull was about 9 cm (about 3.5 in.) long and the body was about 10 cm (about 4 in.) long. The flexible tail, which was about 38 cm (about 15 in.) long, had a diamond-shaped terminal appendage, used as a rudder, in controlling flight. Later pterosaurs, of the Upper Cretaceous period, had a wingspread of more than 6 m (more than 20 ft.). The skull was long and slender and the jaws, were toothless. Although later, pterosaur forms were fairly adept fliers, these creatures are not more ancestral to birds, than are other reptiles.

Early, in 1975, scientists announced that partial skeletons of three huge, long-necked pterosaurs, had been discovered, in the Late Cretaceous non-marine rock, at Big Bend National Park, in Texas. With an estimated wing-span of about 11-12 m (about 36-39 ft.), the Big Bend pterosaur, is the largest flying creature, known to have existed.

Scientific classification: Pterosaurs make up the order,

Pterosauria. The best-known genus, of the early pterosaurs of the late Triassic period is, *Rhamphorhynchus*. The best-known genus, of the later pterosaurs of the Upper Cretaceous period is, *Pteranodon.*

Saber-Toothed Tiger, misnomer for any of several extinct genera of the cat family, Felidae, that lived from the Oligocene to the Pleistocene epochs. The size range of the genera, which possibly evolved independently of one another, was as great as that of, modern cats, but the animals were, in no sense tigers; some paleontologists, even question placing them, with the cats. Their most striking feature, was their enormous, blade-like upper canine teeth, which extended 18 cm (7 in.) or more below the lower jaw; large saber-tooth's, also walked flat-footed, like bears. The animals were heavily muscled, and the jaws opened extremely wide, to permit the canines, to be used. Saber-tooth's, could bring down large prey, such as mastodons, and apparently became extinct, when such animals disappeared, from their habitats.

Stegosaurus, genus of plated, *ornithischian* (bird-hipped) DINOSAURS, that lived, during the late JURASSIC PERIOD, about 150 million years ago. Although, *Stegosaurus* fossils are rare, they have been found in North America, and equally rare, related animals, have been found in China, Europe, and India. The *Stegosaurus* profile, is a familiar dinosaur image, however, with a row of 17 large, triangular, alternating plates, running down the highly arched spine. The body was about 6 m (about 20 ft.) long and 2.5 m (8 ft.) high, at the hips. The head, was remarkably small, for the body, and the tail, bore long spikes. The plates, may have served, a protective purpose, and also, may have helped, to regulate body temperature.

Thecodont, reptilian order of the TRIASSIC PERIOD of earth history, ancestral to the DINOSAUR groups. The name is derived from Latin words meaning "socket-toothed," alluding to the fact, that homodont teeth were implanted in sockets in the jawbones; this characteristic was inherited by the dinosaurs. Most thecodonts were under 1 m (3 ft.) in length, and the hind legs were longer than the front legs - a situation, conducive to bipedal locomotion. Terrestrial thecodonts, were the first animals to walk semi-erect on their hind legs; for many of the dinosaurs that followed, bipedal locomotion, became the norm.

Therapsid, any member of a large group of reptiles, from which, MAMMALS, eventually evolved. Therapsids flourished, during the LATE PALEOZOIC and EARLY MESOZOIC eras, from about 250 million to about 190 million years ago, and subsequently, became extinct. Therapsids, were four-legged, terrestrial reptiles. Some were vegetarian, others were carnivorous. Some therapsids were the size of small rodents, others larger than a modern hippopotamus. Therapsids, had certain attributes, typical of mammals; for example, the teeth of some species, had differentiated into cutting incisors, tearing canines, and grinding molars.

Scientific classification: Therapsids made up the order, Therapsida.

Triceratops, genus of quadrupedal, herbivorous dinosaurs, weighing several tons, that lived during the Cretaceous period, more than 65 million years ago. In all but the earliest species

of the ceratopsian group - to which, *Triceratops* belonged - one or more horns, protruded from the front of the skull, and all ceratopsians, had a parrot-like beak, formed by a unique bone, the rostral. *Triceratops* had three horns - one centrally located, just above the nostrils and a pair that projected from the fore-head - hence, the name. The skull, more than 1.8 (6 ft.) long, in some fossil specimens, was quite large, in proportion, to the rest of the body. A bony frill, at the back of the skull, protected the neck and served to anchor powerful jaw and neck muscles. The ceratopsians appear to have migrated, east to North America, where they became extinct, at the close of the Cretaceous period.

Trilobite, common name for a class of extinct marine arthropods. Trilobites ranged, in length, from a few millimeters up to about 65 cm (26 in.), although most species were between 3 and 7 cm (1 and 3 in.) long. Trilobites, lived during the Paleozoic era, 570 to 250 million years ago and were most prevalent, in the early part of that era. The trilobites, were named for the arrangement of their exoskeleton, or outer shell, into three lobes. The exoskeleton, the part of the organism, that is most commonly preserved, was made of a hard substance; it covered the back of the animal.

Trilobites had two compound eyes. In some trilobites, the eyes had densely packed lenses and may have served merely, as a light sensitive warning device, to detect movement. In other trilobites, they eyes had fewer and more complex lenses and may have been capable, of forming images and perceiving depth.

Trilobites lived in shelf and slope environments, around

continental margins, and in the shallow continental seas, that covered areas of the earth, that today, are land masses. Most trilobites, were bottom dwellers, although some have been, swimmers or floaters. Some, that possessed exceptionally large eyes and a large field of vision, such as *Carolinites*, are thought to have been, swimmers, that inhabited surface waters. Others, with reduced eyes or no eyes at all, preferred deeper, darker waters. Many trilobites, such as *Olenellus*, burrowed into the sea bottom, for protection and to seek food.

Trilobites employed a variety of feeding strategies. Many plowed through mud, at the bottom of oceans and sea, ingesting the sediment, to sort out organic matter. Others were scavengers or predators. Most trilobites, could roll themselves up into a defensive position, so that only the exoskeleton, was exposed.

The fossilized remains of trilobites, are useful, because they help scientists, develop relative time scales, for the ancient marine environment. Because trilobites evolved quickly and were widely distributed, comparing the trilobite fossils found in rock layers in different regions of the earth, can indicate which rock layer, is older than the other. Trilobite fossils, are particularly helpful, in developing time scales, for the early Paleozoic era.

Tyrannosaurus Rex, (Latin, "tyrant-lizard king"), large, bipedal carnivorous DINOSAUR of the family, Tyrannosauridae, of the latter part of the Mesozoic era. About 14 m (about 45 ft.) long, about 5 m (about 19 ft.) tall, and weighing more than 4 metric tons. *Tyrannosaurus*, was well equipped for preying on

the large herbivorous dinosaurs of the time, about 70 million years ago. Its long skull was equipped with powerful jaws, in which, were set sharp, doubly serrated teeth, some, of which, were 15 cm (6 in.) long. The tiny forelimbs, seemingly out of proportion to the rest of the animal's massive body, each bore two sharp claws; the powerful hand limbs, each, were armed with three forward-pointing claws, well-suited for tearing flesh, and a fourth backward-pointing claw. Fossils, that were found in North America (Montana and South Dakota) and Mongolia, in strata of Upper Cretaceous age, indicate that the species came into being and became extinct, in the relatively short space, of a few million years.

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