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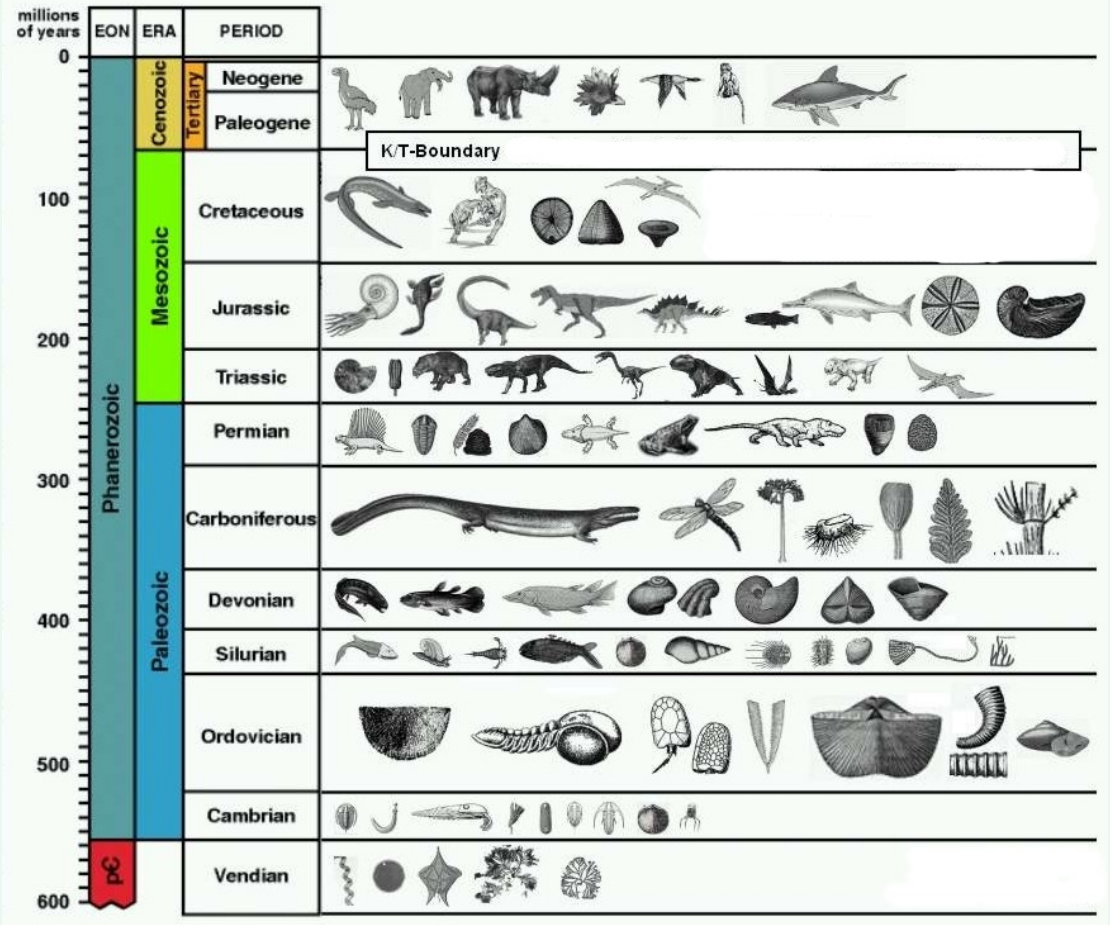
FOSSILS X1

The word fossil is derived from the Latin *fossilis*, which means 'dug up'. Fossils are the remains of creatures which existed long ago. Fossils range from thousands of years to many millions of years in age. The earliest fossils date from around 600 million years ago. However recent reports suggest bacteria may have existed up to 3,000 million years earlier. To put this in context, the dinosaurs became extinct just 65 million years ago. The earth itself is about 4,570 million years old. Geologists divide this vast time into various units according to events which took place in each period. The chart below gives the names of these periods, from the time of the first complex fossils through to the present. It also shows some of the living things (mainly animals) that lived in each period.



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Not all former life was preserved as fossils. The vast majority of living things simply vanished without trace. Fossils come in a variety of sizes, from the microscopic through to large dinosaur skeletons and are formed in a variety of ways.



Permineralised fossils are organisms which became covered by sediment soon after death. As the organism slowly decayed, water infused with minerals passed through it, replacing the chemicals in it with rock-like minerals. Over millions of years the original organism was completely replaced by these minerals and what remains is a rock-like copy of the original. The fossil has the same shape as the original object, but is actually rock. This process results in loss of original colour. The photograph on the right shows the fossil of a huge tree that was formed by the permineralisation process.



In other cases the original remains of the organism completely dissolve and all that is left is an organism-shaped hole in the rock. This kind of fossil is called a mould fossil or typolite. If this hole is later replaced by new, unrelated minerals, it is called a cast fossil. In some cases replacement occurs so gradually that tiny features are preserved despite the total loss of original material. The photograph on the left shows a mould fossil of a shell.



Finally, there are trace fossils: marks in the rock which result from the activities or presence of animals and plants. Examples of these traces include footprints, burrows, root tunnels and even animal droppings (which are called coprolites) and vomit (regurgitaliths). The photograph on the right shows a fossilised dinosaur footprint.

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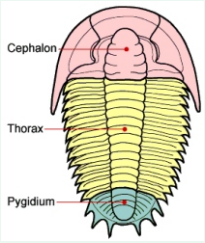
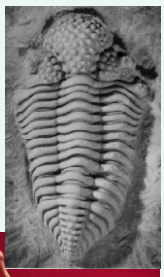
Trilobite



Trilobites first appear in the Cambrian Period and they became extinct in the Permian Period - the group lasted about 300 million years ago. Altogether about 17,000 species of trilobite have been recorded. Photographs of three of these species, illustrating something of their diversity, can seen below right. It is not known what species the trilobite in this box belongs to.



The bodies of trilobites are divided into three parts (left) - a cephalon (head); a thorax composed of freely articulating segments; and a pygidium (tail) composed of the last segments fused together. The thorax seems to have been fairly flexible as fossilised trilobites are often found curled up, like modern woodlice, for protection.



Trilobites range in length from one millimetre to 72cm (1/25inch to 28 inches), with a typical size range of two to seven centimetres (1 to 3½ inches). The world's largest trilobite, *Isotelus rex*, was found in 1998 on the shores of Hudson Bay. One specimen measured 72cm in length (over two feet four inches), 400mm in maximum width (across the cephalon) and 7cm in maximum height.





Many trilobites had eyes. They also had antennae that were probably used for taste and smell. All trilobites lived in the sea, but they found food in a variety of ways and places. Some were blind, probably living too deep in the sea for light to reach them. Some lived on the sea bed, others could swim. Some seem to have been predators, others scavengers.

Trilobites were most diverse during the late Cambrian Period. The last of the trilobites disappeared in a mass extinction at the end of the Permian, about 250 million years ago. This mysterious event - sometimes called the 'Great Dying' - saw the extinction of 96% of all species living in the sea at that time. However, even before this finished them off, it is thought that their numbers began to decrease with the arrival of the first sharks and other early fish in the Silurian and Devonian Periods. These new species had strong, hinged jaws and trilobites may have provided a rich source of food for them.

Carboniferous Limestone



The geological period between about 360 and 300 million years ago is called the Carboniferous Period. This is in turn divided into two parts called the Lower (earliest) and Upper (later) Carboniferous. In Britain the rocks of the Lower Carboniferous Period were laid down under the sea, while those of the Upper Carboniferous Period were made on dry land.

Much of the coal that is found beneath the landscape of Britain was created in the Upper Carboniferous Period. At this time Britain and much of northern Europe was hot and covered by a rainforest which looked superficially similar to that found in Brazil today. When trees die in a stagnant peat swamp environment low oxygen levels prevent their complete decay by bacteria. If these masses of undecayed plant remains are later buried under sediments (mud and sand swept over them by a river or the sea) then coal will form.

This piece of limestone, however, was probably formed under the sea. Limestones can form in many places, including river floodplains and lakes, but they are usually formed in clear tropical waters. Limestones are being made today in such places as the waters of the Bahamas and the Great Barrier Reef off Australia. In such locations the remains of countless sea creatures pile up on the sea bed over millions of years, then slowly change into rock as their chemistry alters. In some places beds of limestone are thousands of metres thick. Huge beds of limestone can be found in the Pennines in northern England, witnesses to the warm tropical waters that once covered the area. It is not known where this example comes from, but fossil shells can be seen embedded in it.

Two Coal Measure Fossils



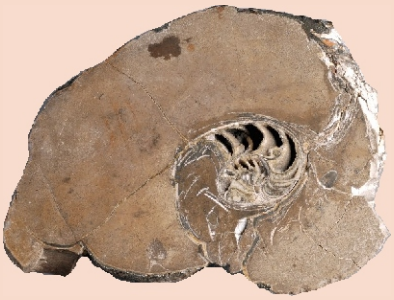
Although the environment that produced coal looked similar to that of Brazil today, the kind of plants that flourished in the Upper Carboniferous Period were, in fact, very different from those found in a modern rainforest.

Tree-sized plants dominated, but these were largely club-mosses - extremely fast-growing and adapted to nutrient-poor, waterlogged soils. It has been estimated that their 1-2 metre wide stems could grow upwards at several metres per year, to a height of 40 metres. They were not seed plants as are most large plants growing today; they reproduced by means of spores. Unlike true trees their trunk contained relatively small amounts of wood. Instead, much of the trunk consisted of soft tissue called periderm, which enabled the plants to grow much more quickly than woody trees. They grew into mature plants, reproduced, and then died. Most modern-day trees, in contrast, reproduce for many years after reaching maturity. For this reason, many palaeontologists call these extinct plants giant herbs rather than trees.

Other plants also grew in the forests, but mainly in the less waterlogged areas, such as on the raised banks of rivers that threaded their way through the swamps. There were tree ferns, looking very similar to those growing today in places like New Zealand. There were also some seed plants belonging to a number of now extinct groups such as the cordaites (distant relatives of today's conifers) and the seed-ferns (distant relatives of the modern cycads). These two mould fossils are witness to this lush, long-since-vanished landscape.



Nautilus



The nautilus is a marine animal whose first ancestors appeared 550 million years ago. This fossil nautilus is from the London Clay rock, which was formed from sediments on the bottom of a shallow subtropical sea about 60 million years ago.



Nautiluses measure about 20 cm long and are protected by a shell that contains many air filled chambers. As the animal grows, new chambers are added behind the outer chamber. The animal lives only in the outermost chamber. A mature nautilus has up to 30 chambers. The photograph on the right shows a shell that has been cut in half. Notice all the chambers inside.

Nautiluses are cephalopod molluscs, like squids and octopuses. These have internal shells and highly developed eyes and brain, but the nautilus is more 'primitive'. It still has the same kind of chambered shell as the ammonites - extinct cephalopods whose fossils can sometimes be found on beaches.

The body, bearing about 90 suckerless tentacles, protrudes from the mouth of the shell underneath a hood which can be pulled down behind it if it needs to withdraw inside the shell for protection.



Despite the fact that they look like snails, nautiluses do not move by crawling across the ocean floor (although they do use their tentacles to scramble about the rocks). Air in the empty shell chambers allows the animals to float and they move by jet propulsion - expelling water through a funnel-like opening to propel themselves in the opposite direction. The picture of the nautilus on the right gives us some idea of what this movement looks like.

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Nautiluses feed on most living marine creatures including molluscs, fish, crustaceans and even other cephalopods. They ambush their prey, then rapidly extend their tentacles to grasp it. The photograph on the right shows a nautilus capturing a crab. Once caught the prey would be devoured by the powerful jaws located at the base of the tentacles, between the eyes.



Traces of iron pyrite (iron sulphide or, more commonly, fool's gold) can be seen on this fossil. This is fairly commonly seen on London Clay fossils. Sometimes entire fossils are made up from iron pyrite. This most frequently occurs with marine fossils because of a process known as bacterial sulphate reduction, in which bacteria cause sulphur and iron minerals to form iron sulphides. The photograph on the right shows an ammonite made up largely of iron pyrite.

Much of a nautilus's life is spent in shallow and surface waters. Their shells cannot withstand the high pressures present in deep water (over about 250 metres).

Sponge



Sponges are one of the most primitive multicellular animals, lacking internal organs, nervous tissue, a circulatory system or a gut for digesting food. To obtain food, the sponges filter the water around them as it passes through tiny pores located on their outer walls. To support and protect their soft bodies, sponges produce skeletons of calcium carbonate, silica, or a soft organic material called spongin.

Sponges date back to a period known as the Neoproterozoic Era, which began 1,000 million years ago, well before the explosion of life forms in the Cambrian Period. It is not known how old this example is or where it originates from. The fossil record of sponges is not abundant, although a famous locality for them is the Cretaceous Faringdon Sponge Gravels in Faringdon, Berkshire (now Oxfordshire).

Belemnite

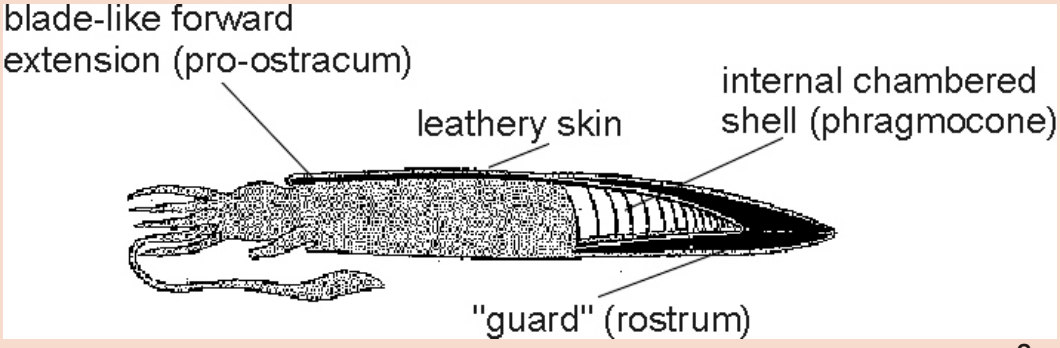


Belemnites are an extinct group of marine animals, similar in many ways to the modern squid and cuttlefish. Like them, the belemnites possessed an ink sac, but, unlike the squid, which has eight arms and two tentacles, they possessed ten arms and no tentacles. Also, unlike the modern squid, whose arms have suckers, belemnite arms carried a series of small hooks for grabbing prey. Belemnites were carnivores that caught small fish and other marine animals with their arms and ate them with their beak-like jaws. Belemnites themselves appear to have formed part of the diet of marine reptiles such as ichthyosaurs, whose fossilised stomachs frequently contain many belemnite hooks.



Normally only the back part of the belemnite shell (called the guard or rostrum) is found. The guard is elongated and bullet-shaped, being cylindrical and either pointed or rounded at the rear end. The front of the guard would have been hollow and would have enclosed a chambered section of shell. This section, which seldom survives, was divided into chambers that were gas-filled and which caused the animal to remain buoyant. The diagram below shows the structure of a typical belemnite. The picture on the right shows what a belemnite may have looked like in life. Like ammonites, belemnites moved by squirting out a jet of water which propelled them forwards.

Belemnites reached their greatest abundance and diversity during the Jurassic and early Cretaceous Periods, but, like the ammonites, disappeared at the end of the Cretaceous Period.



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Chert and Flint Rocks



The red/brown rock is probably chert. Most beds of chert are formed from the ooze that covers the deep ocean floor. The ooze is built up from the constant rain of plankton that drops to the floor when these small organisms die. Once the ooze is buried it solidifies into chert. This example contains the mould fossil of a sea-urchin-like creature.





Living sea urchins (left) are covered with spines, but these usually decay quickly after death leaving a shell, which is also called the test. Fossilised sea urchin tests are relatively common. The earliest sea urchins are found in the Ordovician Period. The photograph below right shows fossilised sea urchin tests from the Cretaceous Period.



Not all chert is biochemical in origin. Sometimes the calcite crystals in limestone are gradually replaced by silica. Flints, the nodules of black or toffee coloured rock that are common in the landscape around Reading, are an example of this process. Sometimes, when these nodules are split open, they are found to have a cavity in the centre in which there are fossil remains. The flint example in this box has such a cavity, which may well have been formed by a sponge, although there are no traces of a fossil as it is now.

Leaf Impression & Fossilised Wood from the Reading Beds



The Reading Beds are layers of clay and sands, mixed with pebbly beds and masses of fine sand converted into quartzite, that were deposited between 56 and 55 million years ago, during the Paleogene Period. These beds were created when the area was a river estuary receiving river sediment from land lying to the west. They are named after the town of Reading, Berkshire, although they (and other related formations) are found throughout the London Basin. The impression of leaves can be seen on one of these samples, while the others are good examples of fossil wood formed by permineralisation.



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Two London Clay Fossils



The London Clay consists of a stiff, bluish coloured clay which becomes brown when weathered. The bed was laid down between 54 and 48 million years ago on the shallow shelf of a semitropical sea near the estuary of a major river system. Fossil evidence suggests that the nearest land mass lay approximately 100 kilometres to the north and east, and was probably fringed by mangrove swamps and palms. Behind, a tropical rain forest was teeming with a diversity of plants and animals. Offshore, islands and mud banks clad with palm trees harboured birds, turtles and crocodiles. The seas would have supported large populations of sharks, rays and fish including swordfish and sturgeon. The many logs that floated out to sea formed rafts which slowly became waterlogged and sank to the bottom. Crabs, lobsters, gastropods and bivalve molluscs all thrived in this environment.

These two fossils illustrate this environment. One is the exoskeleton of a crab. Crabs have to shed these shells in order to grow and the majority of crab fossils found in the London Clay are the result of this process. They are almost always found within pale ochre nodules with the fossil itself black where it is exposed. The second example shows a scattering of bivalve shells and shell-fragments.

Whale Ear Bone



Toothed whales use sound to navigate through their dark underwater environment. They produce a sound that is beamed out into the water and from the way the sound bounces back they are able to 'see' the world around them. Bats use a similar process of echolocation to hunt in the dark.

The ear bones of all whales are extremely hard and dense, and they are commonly preserved as fossils in marine sediments. The internal bony structures related to hearing functions are often preserved in exquisite condition and can provide evidence for the way whales have evolved.

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It is thought that 50 million years ago marine whales began to evolve from a terrestrial wolflike ancestor called Pakicetus. Their transition to fully fledged aquatic creatures took about 15 million years. On land, sound vibrations strike the mammalian eardrum through an air-filled, outer ear canal. But when a mammal is submerged water fills the ear canal, diminishing the ability of the eardrum to transmit sound.

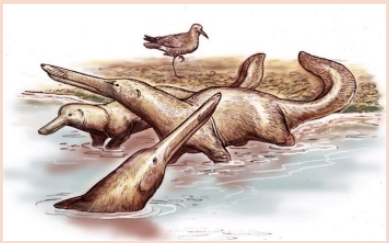
Fossil ears from whale-ancestors living 43 to 46 million years ago - called Remingtonocetids (which still retained short legs, long tails, and long snouts) and Protocetids (that had powerful hind limbs for swimming) - show that they had developed a system whereby sound vibrations were detected from the water and transmitted to the ear through a large pad of fat in the lower jaw. They retained, however, the air-filled outer ear canal for hearing on land.

By around 40 million years ago Basilosauroids - massive, snakelike animals with tiny residual hind limbs that would not have been able to leave the water - had evolved air-filled sacs that allowed the high-definition, directional underwater hearing that is used by whales today, although they did not yet use echolocation.



Left: A Pakicetus.

Right: Remingtonocetid Kutchicetus.





Left: A Protocetid

Right: A Basilosaurus.



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Ichthyosaur Vertebral Column, Jaw & Tooth







Ichthyosaurs were giant marine reptiles resembling fish and dolphins and appeared about 250 million years ago (earlier than the dinosaurs, who put in an appearance about 230 million years ago) and became extinct about 90 million years ago (about 25 million years before the same thing happened to the dinosaurs). Ichthyosaurs evolved from as-yet unidentified land reptiles that moved back into the water in a development parallel to that of dolphins and whales. The late Triassic and early Jurassic Periods were the heyday of the ichthyosaurs, which are represented by four families and a variety of species, ranging from one to ten meters in length.



Ichthyosaurs are important in the history of palæontology (the study of prehistoric life forms), as their fossil remains are relatively common in southern Britain and they were one of the first groups of extinct species to be studied. They were first described in 1699 from fossil fragments discovered in Wales. The first complete ichthyosaur fossil was found in 1811 by Mary Anning in Lyme Regis, along what is now called the Jurassic Coast. She subsequently discovered three separate species. The ichthyosaur skeleton on the right was found in Dorset.

The jaw and tooth specimens in this box indicate the carnivorous feeding habits of ichthyosaur species. Ichthyosaur jaws were typically studded with even rows of pointed conical teeth. Ichthyosaur teeth are often striated (grooved), like these examples. In most species the teeth were so closely spaced that when the jaws closed they meshed together, leaving no gaps - perfect for catching fish. Modern porpoises and dolphins have teeth and jaws similar to those of ichthyosaurs. We also know about the diets of some ichthyosaurs from the stomach contents preserved in fossils, which indicate that many of the fish-shaped ichthyosaurs relied heavily on belemnites. Some late ichthyosaur stomachs have been found to contain bony fish and hatchling-sized baby turtles.

When ichthyosaurs first appeared they probably swam like eels, by undulating the entire body, and had flat-ended vertebrae. The vertebrae in this box are indented at their ends, which suggests they belonged to a more fish-shaped ichthyosaur from later in their history.