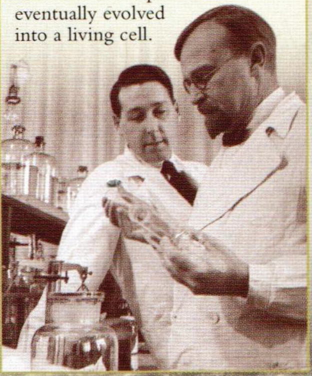
# THE HISTORY OF OCEAN LIFE

**LIFE HAS BEEN PRESENT IN THE OCEANS** for over 3.5 billion years. The great diversity of today's marine life represents only a minute proportion of all species that have ever lived. Evidence of early life is hard to find, but it is seen in a few ancient sedimentary rocks. The fossil record has many gaps, but it is the only record of what past life looked like. Fortunately, many marine organisms have shells, carapaces, or other hard body parts, such as bones and teeth. They are more likely to be preserved than entirely soft-bodied creatures, although in exceptional circumstances these have also been fossilized. Using fossils, and information from the sediments in which they are preserved, scientists can reconstruct the history of marine life.

PEOPLE

### A.I. OPARIN

In 1924, Russian biochemist Aleksandr Oparin (1894–1980) theorized that life originated in the oceans. He suggested that simple substances in ancient seas harnessed sunlight to generate organic compounds found in cells. These compounds eventually evolved into a living cell.



**EARLY MICROFOSSILS**
This micrograph of a section of chert (a form of silica) from the Gunflint Formation, Canada, includes 2-billion-year-old microfossil remains. These microfossils contain the oldest and best-preserved fossil cells known.

## 3,800–2,200 MILLION YEARS AGO THE ORIGIN OF LIFE

When Earth formed, it was totally unsuitable for life. The atmosphere changed, however, and the oceans formed and cooled (see pp.44–45), so that by 3.8 billion years ago, conditions allowed biochemical reactions to take place. It is thought that simple, water-soluble organic compounds called amino acids accumulated in the water, eventually forming chains and creating proteins. These combined with other organic compounds, including self-replicating DNA, to form the first living cells.

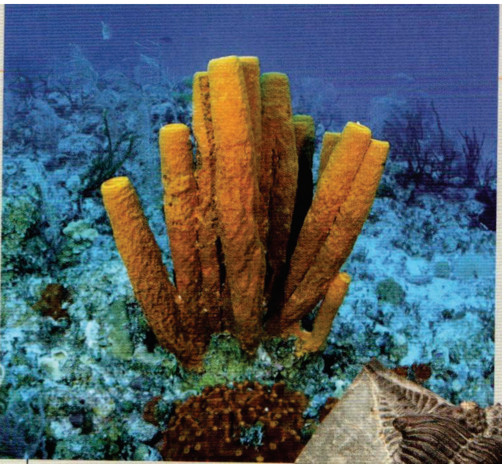
Earth's atmosphere was further developed by mats of algae and cyanobacteria called stromatolites, whose fossil record stretches from over 3.5 billion years ago to the present day. Stromatolites could perform photosynthesis, and their growth eventually flooded the atmosphere with oxygen. Cyanobacteria are single-celled organisms with DNA but no nucleus or complex cell organelles. It was not until 2.2 billion years ago that cells with nuclei and complex organelles (eukaryote cells) appeared.

## 620–542 MYA PRECAMBRIAN LIFE

Ancient life, though soft-bodied, fossilizes under certain conditions, offering rare glimpses of early multicellular life. About 620 million years ago, a community of soft-bodied animals known as the Ediacaran fauna left their body impressions and trackways in a shallow sea bed. The sea bed now forms the sandstone of the Ediacaran Hills in Australia, where the fauna was discovered in the 1940s.

The ancient sea was inhabited by strange, multicellular animals. Some resembled worms and jellyfish, but others were thin, flat, and unfamiliar, making it difficult to know if they are related to existing animals or a separate, extinct, evolutionary line. These animals are the only link between the single-celled organisms that preceded them and the rapid diversification of life that followed. Ediacaran fauna are also found in Namibia, Sweden, Eastern Europe, Canada, and the UK.

**EDIACARAN FOSSILS**
These are typical examples of Ediacaran fossils preserved as impressions in rock. Mawsonite (left) is believed to be a complex animal burrow; Spriggina (below) may be an arthropod, or a new life-form.

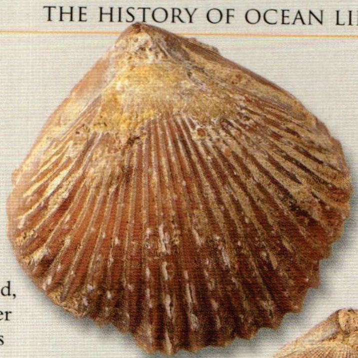


FIRST REEFS
The Cambrian reefs were built by extinct sponges called archaeocyathids. They resembled tube sponges (above), having a similar shape and a calcareous skeleton.

ARTHROPOD TRAILBLAZERS
Trilobites evolved a multitude of different body forms and remained a ubiquitous arthropod group for the next 100 million years. They became extinct during the Permian period.

## 550–530 MYA CAMBRIAN EXPLOSION

Over 20 million years around the start of the Cambrian period, many life-forms made a sudden appearance. Indeed, most of today's major animal groups (phyla) abruptly appear in the fossil record. The Cambrian Explosion of evolution may have been caused by the creation of new ecological niches as the coastline increased, due to the breakup of the Rodinia supercontinent. Further niches arose as a rise in sea level produced large expanses of warm, shallow water. The Cambrian seas were dominated by arthropods, chiefly trilobites, but there were also foraminiferans, sponges, corals, bivalves, and brachiopods. All readily fossilize, as they each have some sort of mineralized "skeleton."

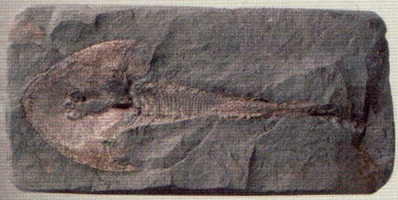


BRACHIOPODS
Brachiopods may resemble bivalve mollusks, but they are unrelated life-forms and were among the first animals to appear in the Cambrian period. Over 3,000 genera have been described. Only 300 species survive today.

LIVING MARINE STROMATOLITES
Built by Earth's oldest type of organism, stromatolites are now found in only a few places, such as here, in the hyper-saline water of Hamelin Pool, Australia.

## 418–354 MYA THE AGE OF FISH

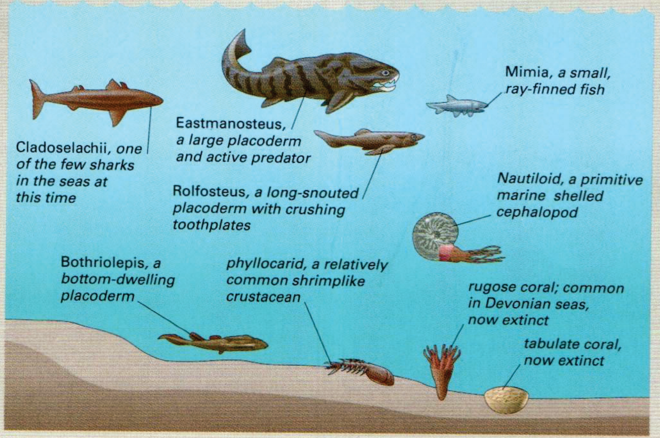
The earliest vertebrate fossils known are jawless fish that lived some 468 million years ago. Jawed fish appeared in the Silurian period, following the development of massive coral and sponge reefs that provided them with a multitude of habitats in which to diversify. The now-extinct acanthodians, with their prominent spines on the leading edges of their fins, were among the earliest of these. Having hinged jaws allowed fish to feed more efficiently, and paired fins gave them the speed and maneuverability to hunt. The following Devonian period (418–354 million years ago) saw an evolutionary radiation that could be called the "Age of Fish." Armored fish called placoderms dominated Devonian seas, some reaching lengths of 20 ft (6 m). Ray-finned fish, sharks, and lobe-finned fish also appeared at this time and have survived to the present day, although marine lobe-finned fish are known only from the coelacanth. Lobe-finned fish are important in the fossil record because one group gave rise to early tetrapods (limbed vertebrates).



EARLY JAWLESS FISH
Jawless fish first evolved in the ocean, later spreading into brackish and freshwater habitats. The bony head shield and dorsally situated eyes of this *Cephalaspis* suggest it is a bottom-dweller.

EVOLUTIONARY INSIGHT
This lobe-finned fish, *Tiktaalik roseae*, has gills and scales like a fish, but has tetrapod-like limbs and joints. This "missing link" helps to reveal how animals moved from the oceans onto land.

DEVONIAN COMMUNITY
The Devonian reef fauna (right) from Gogo, Australia, is typical of the time. It is dominated by a wide variety of armored placoderms, but ray- and lobe-finned fish, and a shark, have also been found there.

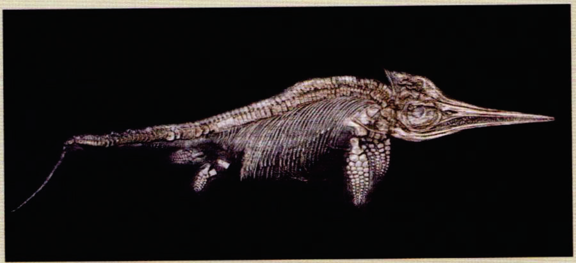


## 252–65 MYA GIANT MARINE REPTILES

During Triassic, Jurassic, and Cretaceous times, evolution of reptiles, similar to that of the dinosaurs on land, occurred in the oceans. Between 252 and 227 million years ago, three groups appeared—turtlelike placodonts, lizardlike nothosaurs, and dolphinlike ichthyosaurs. Of these, only ichthyosaurs survived until the Jurassic.

The Jurassic oceans teemed with life. Modern fish groups were well represented, as were ammonites, mollusks, squid, and modern corals. A variety of ichthyosaurs evolved, some giant forms reaching 30 ft (9 m) in length, but they soon died out and were replaced by modern sharks.

The gap left by the extinction of the placodonts and nothosaurs was filled by long-necked plesiosaurs. Those with a short body and tail and a small head lived in shallow water, while larger forms, called pliosaurs, probably lived in deep water. It is also likely that some of the flying reptiles, called pterosaurs, lived on coastal cliffs and survived by eating fish caught at the water's surface. During the Cretaceous Period, reptiles remained the largest marine carnivores, (plesiosaurs now coexisting with mosasaurs, distant relatives of monitor lizards,) but none survived the mass extinction that occurred 65 million years ago.

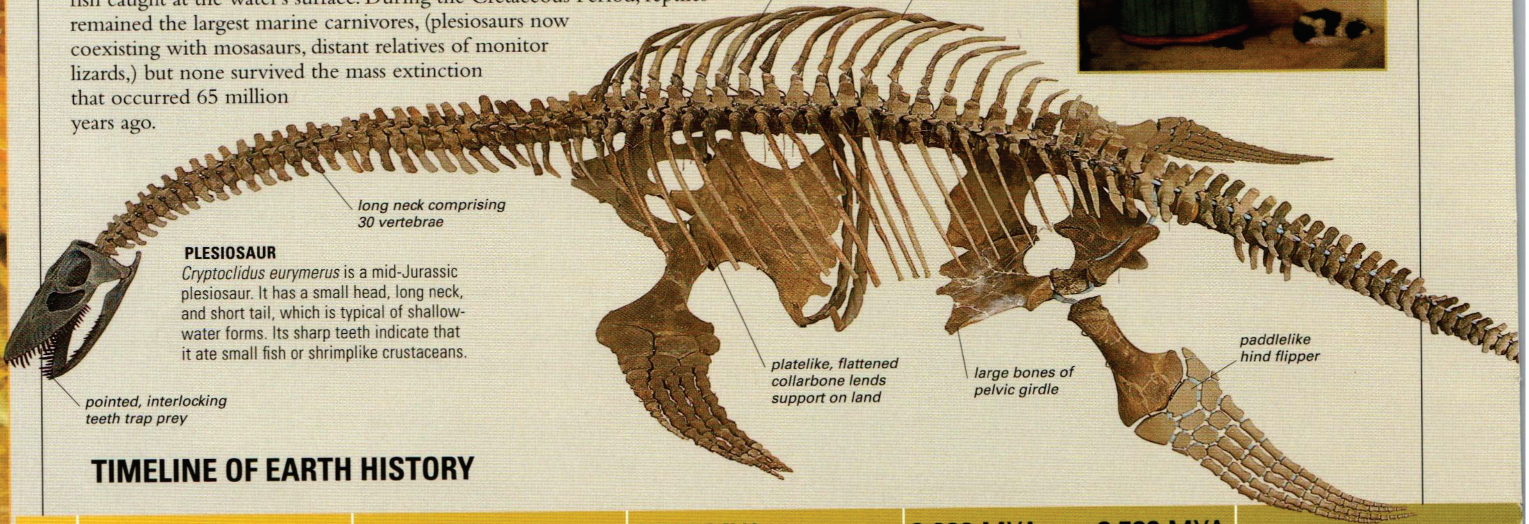


**FOSSILIZED ICHTHYOSAUR**
The dolphinlike features of this ichthyosaur are evident from its fossilized remains. The powerful tail was half-moon-shaped, but here only the down-turned backbone is preserved.

**PEOPLE**

### MARY ANNING

Lyme Regis in Dorset, UK, is famous for its Jurassic fossils, and is where Mary Anning (1799–1847) found and collected her now-famous ichthyosaur and plesiosaur skeletons. She was one of the first professional fossil collectors.




**PLESIOSAUR**
*Cryptoclidus eurymerus* is a mid-Jurassic plesiosaur. It has a small head, long neck, and short tail, which is typical of shallow-water forms. Its sharp teeth indicate that it ate small fish or shrimplike crustaceans.

### TIMELINE OF EARTH HISTORY

Million years ago | 4,100 MYA | 4,000 MYA | 3,500 MYA | 3,000 MYA | 2,500 MYA | 2,200 MYA

CRYPTOZOIC EON 4,500–542 MYA

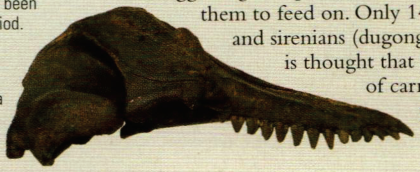
first organic molecules; first stromatolites; first microfossils; first eukaryotes and multicellular algae

**ANCIENT WHALE SKELETON**
This skeleton has been exposed in a desert in Saccao, Peru. Whales evolved over the last 50 million years, so this area must have been an ancient sea at some point in this period.

## 50–14 MYA RETURN TO WATER

Following the mass extinction that saw the demise of marine reptiles, some mammals that had evolved on land began returning to the water. Around 50 million years ago, the oceans started to resemble modern oceans in terms of their geographical positions and fauna. The ancestors of whales, however, were unlike their modern counterparts. The earliest whale, *Pakicetus*, was probably a close relative of the hoofed mammals (ungulates), but it is known only from its skull. *Ambulocetus*, which means "walking whale," is another early form. It had few adaptations for living in water and probably still spent much time on land.

The productivity of the oceans increased, whales diversified, and other marine mammals appeared. Whales similar to today's toothed whales appeared first, and a few million years later, baleen whales evolved. By 24 million years ago, baleen whales had reached today's giant sizes, suggesting that plankton was present in vast numbers for them to feed on. Only 14 million years ago, pinnipeds and sirenians (dugongs and manatees) evolved. It is thought that pinnipeds arose from a family of carnivores not unlike otters. Their present-day forms are seals, sea lions, and walruses.



**SKULL WITH A BLOWHOLE**
The nostrils of *Prosqualodon davidi* are positioned on top of the head, forming a blowhole. This feature proves that this fossil skull is from a primitive whale.

**HUMAN IMPACT**

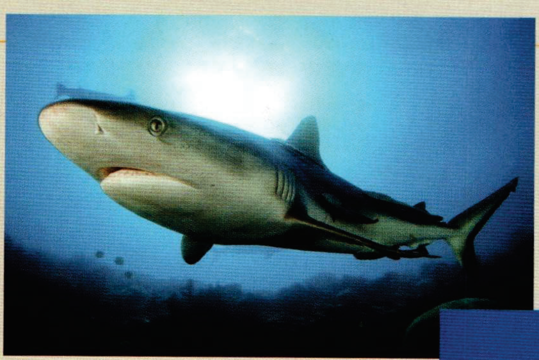
### LIFE ON THE MOVE

Humans have long had a profound effect on the oceans through pollution, overfishing, and linking oceans with canals. People have also transported marine organisms all over the world, in and on their ships, without knowing what long-term impact this will have.

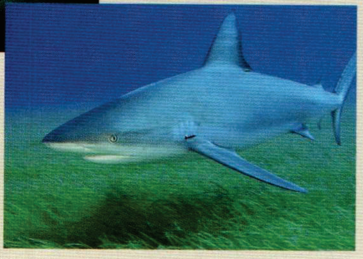
# TODAY: LIFE IN MODERN OCEANS

We know much more about life in today's oceans because, as well having entire organisms to study, we can also observe life cycles, locomotion, and behavior. Each of the five oceans supports a wide variety of life. Some species are very specialized and are restricted to a small area, while others are migratory or generalists and have a wider distribution. Sometimes, closely related species live in the same habitat in different oceans, separated by land or other physical barriers (see right).

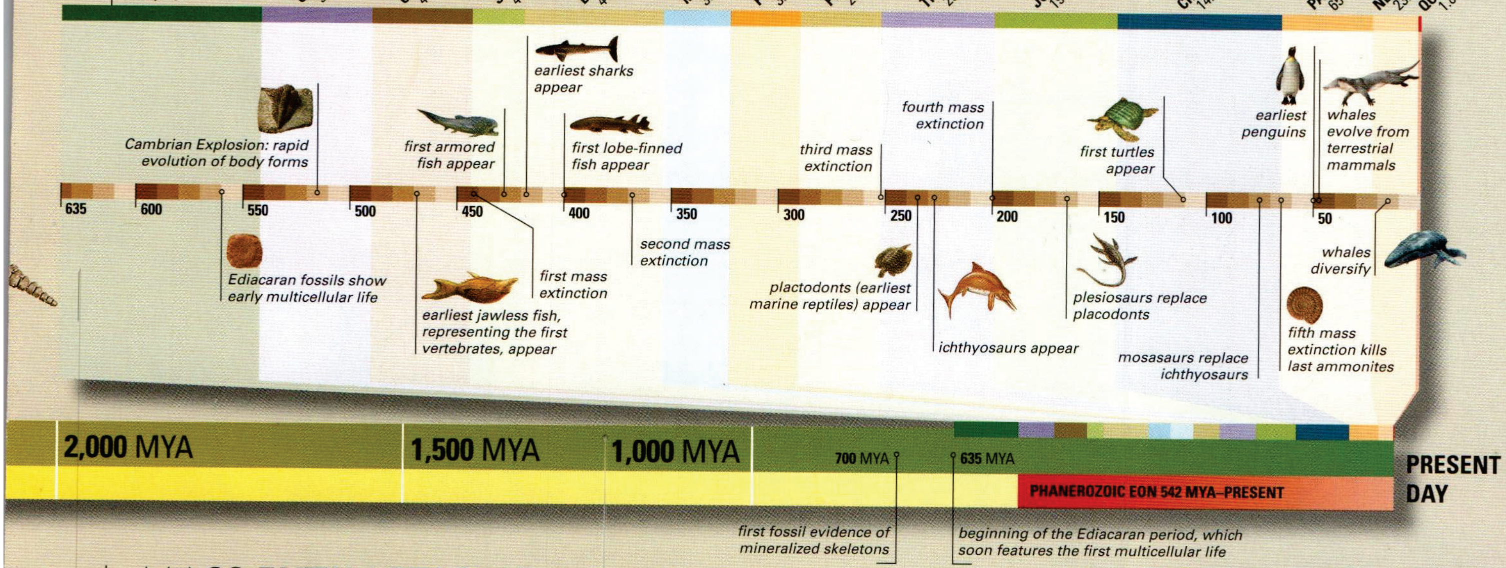
By studying living organisms and the characteristics of the water they live in, scientists can also better understand ancient ocean environments and organisms. The deep ocean is still poorly known, but it contains an ecosystem that could be crucial to our understanding of life—black smokers (see p.188). Isolated from sunlight and from the surrounding water by a steep thermal gradient, it is possible that this is the type of environment in which life first evolved 3.5 billion years ago.



**GRAY REEF SHARK**
Like its close relative the Caribbean reef shark (below), this shark lives in warm, shallow waters, near coral atolls and in adjacent lagoons. It is found in the Indian and Pacific oceans, but it is cut off from the Atlantic.



**CARIBBEAN REEF SHARK**
Like the gray reef shark (above), this species lives in shallow water near coral reefs. Its range is isolated from the Indo-Pacific by the deep, cold ocean around South Africa, so it is restricted to warm parts of the Atlantic, from the Caribbean to Uruguay.




# MASS EXTINCTIONS

The history of life is punctuated by five mass extinctions—catastrophic events in which many life forms died out. The first occurred 443 million years ago, when prominent marine invertebrates disappeared from the fossil record. About 368 million years ago, global cooling and an oxygen shortage in shallow seas caused about 21 percent of marine families to disappear, including corals, brachiopods, bivalves, fishes, and ancient sponges. At the end of the Permian Period, 252 million years ago, the cooling and shrinking of oceans killed over half of all marine life. Another mass-extinction event at the end of the Triassic Period, 199.5 million years ago, caused major losses of cephalopods, especially the ammonites.

The fifth extinction, 65 million years ago, caused the demise of the dinosaurs; in the oceans, it caused the giant marine reptiles to disappear. The next mass extinction is likely to be a result of human activity.

**AMMONITE FOSSIL**
This ammonite species is one of the few to survive the late-Triassic mass extinction event.

**VOLCANIC ARMAGEDDON**
Volcanic activity in the western Ghats of India is now thought to have been a factor in the most recent mass extinction. The eruptions would have caused destruction and climate change on a global scale.