

Key Idea: Fossils provide a record of the appearance and extinction of organisms. The fossil record can be used to establish the relative order of past events.

The importance of the fossil record

- ▶ **Fossils** are the remains of long-dead plants and animals that have become preserved in the Earth's crust.
- ▶ Fossils provide a record of the appearance and extinction of organisms, from species to whole taxonomic groups.
- ▶ The fossil record can be calibrated against a time scale (using dating techniques), to build up a picture of the evolutionary changes that have taken place.



Fossilized fern frond

Gaps in the fossil record

The fossil record contains gaps and without a complete record, it can sometimes be difficult to determine an evolutionary sequence. Scientists use other information (e.g. associated fossils and changes in morphology) to produce a order of events that best fits all the evidence.

Gaps in the fossil can occur because:

- ▶ Fossils are destroyed.
- ▶ Some organisms do not fossilize well.
- ▶ Fossils have not yet been found.

Profile with sedimentary rocks containing fossils

Rock strata are layered through time

Rock strata are arranged in the order that they were deposited (unless they have been disturbed by geological events). The most recent layers are near the surface and the oldest are at the bottom. Fossils can be used to establish the sequential (relative) order of past events in a rock profile.

New fossil types mark changes in environment

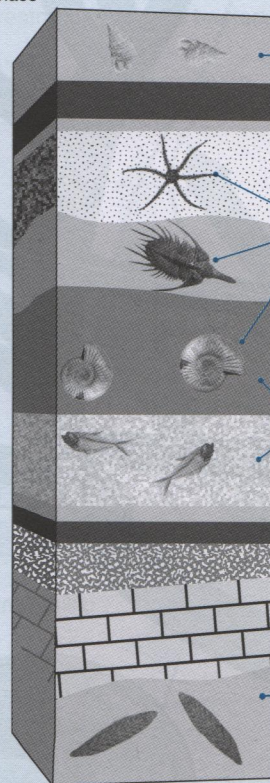
In the strata at the end of one geological period, it is common to find many new fossils that become dominant in the next.

Each geological period had a different environment from the others. Their boundaries coincided with drastic environmental changes and the appearance of new niches. These produced new selection pressures, resulting in new adaptive features in the surviving species as they responded to the changes.

Ground surface

Youngest sediments

Oldest sediments



Recent fossils are found in more recent sediments

The more recent the layer of rock, the more resemblance there is between the fossils found in it and living organisms.

Extinct species

The number of extinct species is far greater than the number of species living today.

Fossil types differ in each stratum

Fossils found in a given layer of sedimentary rock are generally significantly different to fossils in other layers.

More primitive fossils are found in older sediments

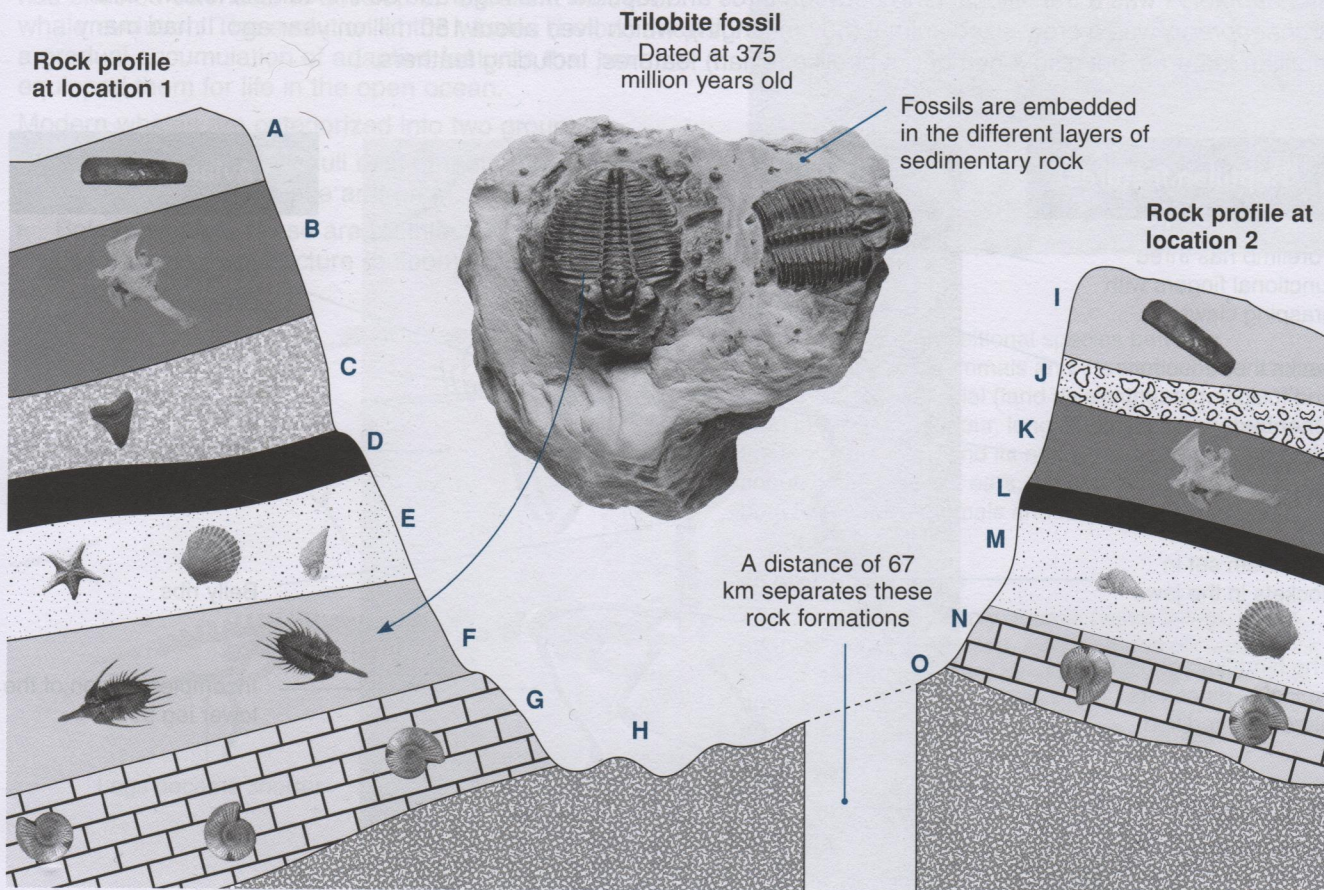
Fossils in older layers tend to have quite generalized forms. In contrast, organisms alive today have specialized forms.

1. Discuss the importance of fossils as a record of evolutionary change over time: _____

2. Why can gaps in the fossil record make it difficult to determine an evolutionary sequence? _____

Key Idea: Analyzing the fossils within rock strata allows scientists to order past events in a rock profile, from oldest to most recent.

The diagram below shows a hypothetical rock profile from two locations separated by a distance of 67 km. There are some differences between the rock layers at the two locations. Apart from layers D and L which are volcanic ash deposits, all other layers comprise sedimentary rock. Use the information on the diagram to answer the questions below.



- Assuming there has been no geological activity to disturb the order of the rock layers, state in which rock layer (A-O) you would find:
 - The youngest rocks at Location 1: _____
 - The oldest rocks at Location 1: _____
 - The youngest rocks at Location 2: _____
 - The oldest rocks at Location 2: _____
- State which layer at location 1 is of the same age as layer M at location 2: _____
 - Explain the reason for your answer in 2 (a): _____

- State which layers present at location 1 are missing at location 2: _____
 - State which layers present at location 2 are missing at location 1: _____
- The rocks in layer H and O are sedimentary rocks. Why are there no visible fossils in these layers?

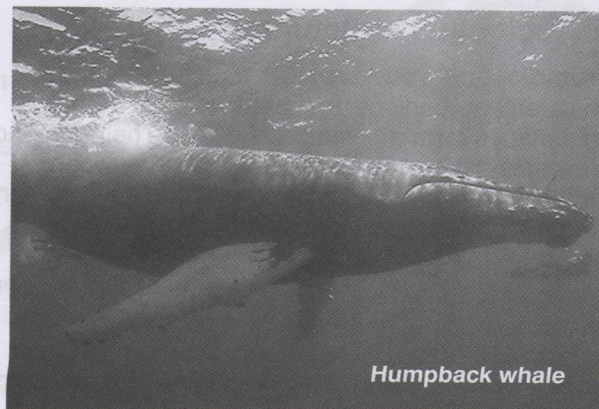
Key Idea: The evolution of whales is well documented in the fossil record, with many transitional forms recording the shift from a terrestrial to an aquatic life.

Whale evolution

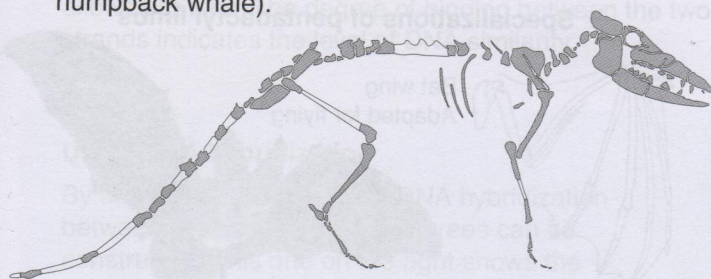
The evolution of modern whales from an ancestral land mammal is well documented in the fossil record. The fossil record of whales includes many transitional forms, which has enabled scientists to develop an excellent model of whale evolution. The evolution of the whales (below) shows a gradual accumulation of adaptive features that have equipped them for life in the open ocean.

Modern whales are categorized into two groups.

- ▶ Toothed whales have full sets of teeth throughout their lives. (e.g. sperm whale and orca).
- ▶ Baleen whales. These are toothless whales and they use a comb-like structure (baleen) to filter food (e.g. humpback whale).

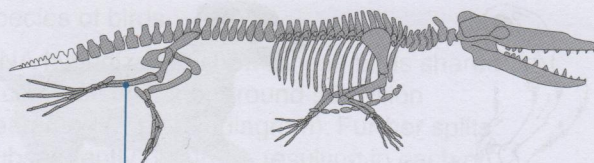


Humpback whale



50 mya *Pakicetus*

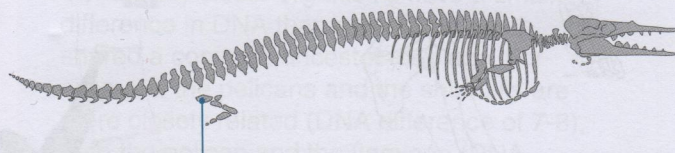
Pakicetus was a transitional species between carnivorous land mammals and the earliest true whales. It was mainly terrestrial (land dwelling), but foraged for food in water. It had four, long limbs. Its eyes were near the top of the head and its nostrils were at the end of the snout. It had external ears, but they showed features of both terrestrial mammals and fully aquatic mammals.



Legs became shorter

45 mya *Rhodocetus*

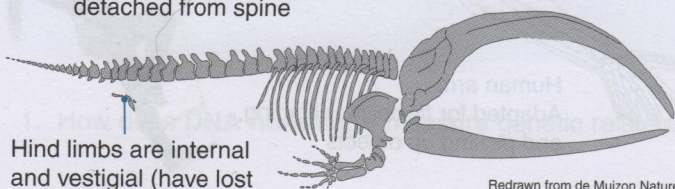
Rhodocetus was mainly aquatic (water living). It had adaptations for swimming, including shorter legs and a shorter tail. Its eyes had moved to the side of the skull, and the nostrils were located further up the skull. The ear showed specializations for hearing in water.



Hind limbs became detached from spine

40 mya *Dorudon*

Dorudon was fully aquatic. Its adaptations for swimming included a long, streamlined body, a broad powerful muscular tail, the development of flippers and webbing. It had very small hind limbs (not attached to the spine) which would no longer bear weight on land.



Hind limbs are internal and vestigial (have lost their original function).

Redrawn from de Muizon Nature 2001
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Balaena (recent whale ancestor)

The hind limbs became fully internal and vestigial. Studies of modern whales show that limb development begins, but is arrested at the limb bud stage. The nostrils became modified as blowholes. This recent ancestor to modern whales diverged into two groups (toothed and baleen) about 36 million years ago. Baleen whales have teeth in their early fetal stage, but lose them before birth.

1. Why does the whale fossil record provide a good example of the evolutionary process? _____

2. Briefly describe the adaptations of whales for swimming that evolved over time: _____