LEAF-SHAPED ANIMALS
This 8-inch (20-centimetre) *Thaumaptilon* fossil, from the Burgess Shale, is very similar to some Vendian leaf-shaped Ediacarans, such as *Charnia*. Some scientists argue that the two are related. It may also be a 530-million-year-old ancestor of the living seapens, which are colonial animals related to the corals.

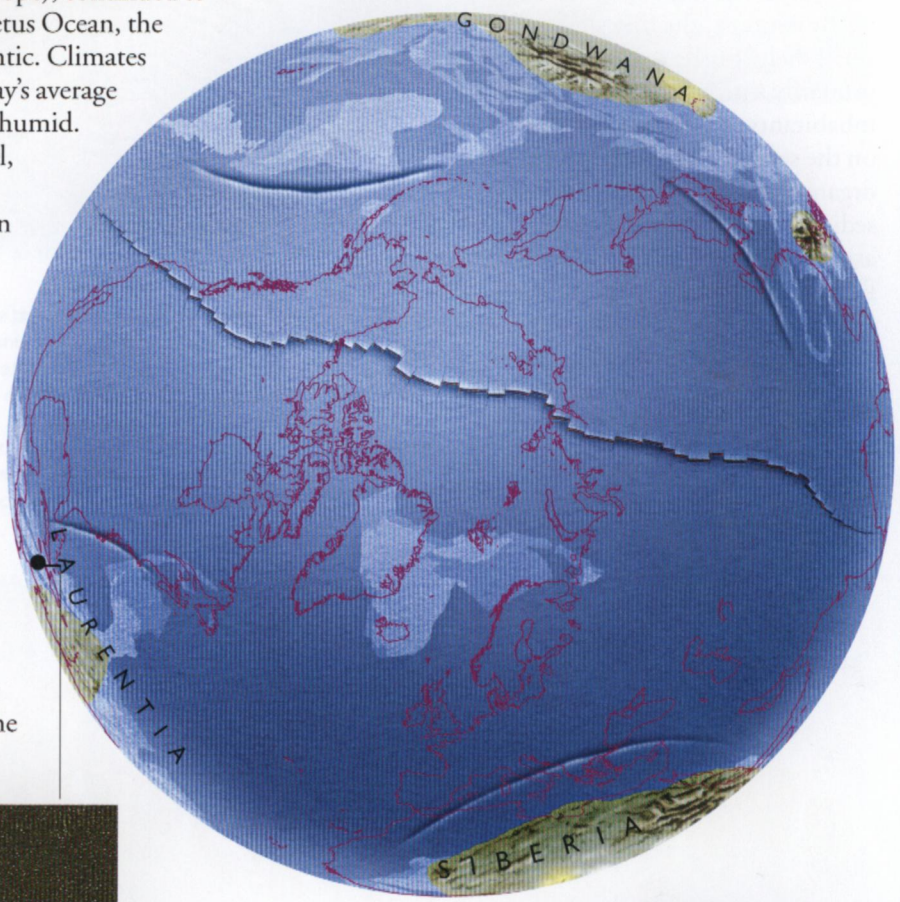
Late Cambrian Period

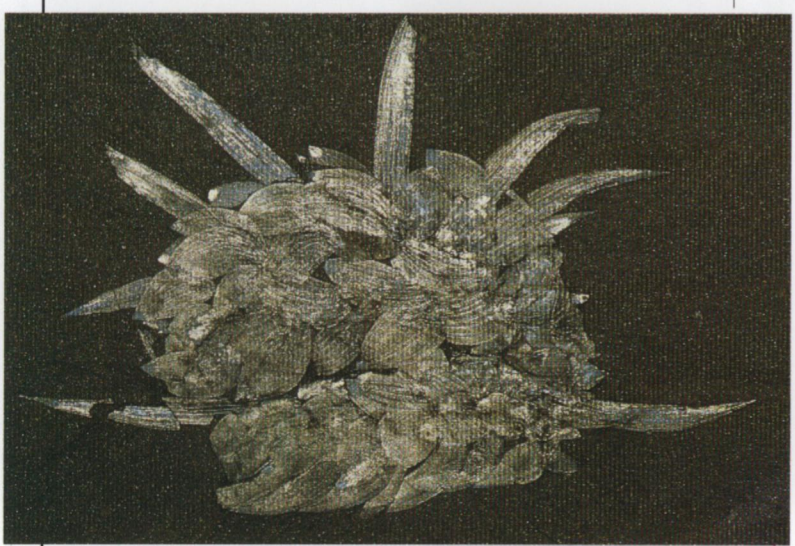
THIS PERIOD WAS MARKED BY THE CONTINUING SUCCESS OF ARTHROPODS, SUCH AS THE TRILOBITES, AND THE EMERGENCE OF A POSSIBLE ANCESTOR OF THE VERTEBRATES.

As the world emerged from the "icehouse" state of the glaciated late Precambrian times, the supercontinent of Pannotia, made up of the southern continent of Gondwana, Laurentia (North America), Baltica (Eurasia), Siberia (Asia) and Avalonia (western Europe), continued to break up, creating the Iapetus Ocean, the forerunner of today's Atlantic. Climates warmed to well above today's average temperatures and became humid. The general rise in sea level, which had started at the beginning of the Cambrian age, continued, and lasted into late Cambrian times. By then over half of the North American continent was flooded by shallow seas.

EXTINCTION EVENTS
These warm, light-filled waters were an ideal environment for life to expand and diversify, but progress was not smooth. There were two large-scale extinction events, one at the end of the Precambrian, and a more drastic one at the beginning of mid-Cambrian times, some 530 million years ago, when up to 70 per cent of species disappeared.

Although creatures such as the numerous cone-shaped archeocyathans became extinct, other more





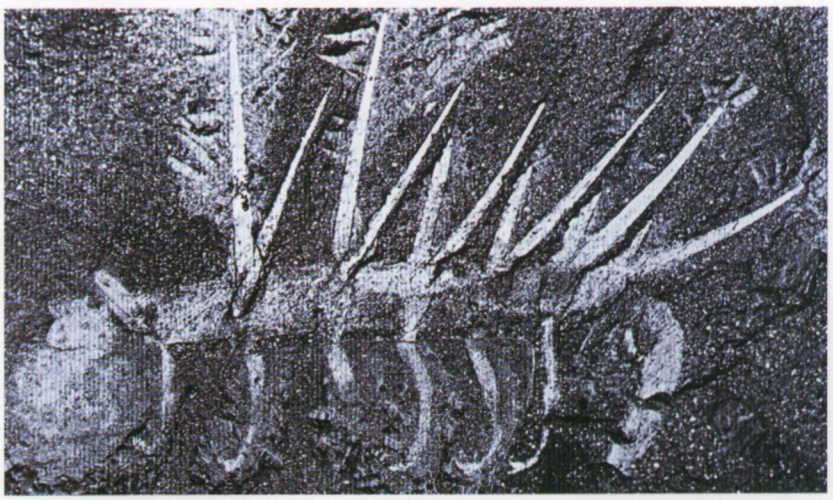
ARMOURED SLUG
Scaly armour-plating covers this slug-like creature, *Wiwaxia*, 1.5 inches (4 centimetres) long, from the Burgess Shale, Canada. The scales are hollow and covered with a lattice of intersecting ribs. They may have been iridescent, flashing colour signals to attract mates.

MASS EXTINCTION

The mass extinction event that occurred halfway through the Cambrian period seems to have been caused by fluctuating sea levels. As sea levels rose from the low levels of the late Precambrian age, marine animals colonized the expanding shelf seas. Mid-Cambrian sea levels fell again, destroying the shallow-water environments and wiping out large numbers of marine species.

successful and aggressive predatory creatures had evolved by mid-Cambrian times, such as *Anomalocaris* and *Laggania*, which had actively biting mouths. Other carnivorous predators were mostly worms, which swallowed their prey whole.

Arthropods, including the trilobites, were the most common marine organisms of the period, and continued to develop and thrive. Many had increasingly armoured bodies, often covered in spines and chainmail-like "sclerites" (plates), for defending themselves against predators. Eventually the arthropods covered themselves in hard shells, constructed from the carbonates and phosphates present in the seawater.



STRANGE, SPIKED CREATURE
This Burgess Shale animal is very strange, as its name, *Hallucigenia*, suggests. The stiff spikes on top were initially thought to be its legs and the flexible appendages underneath its feeding apparatus, but scientists have since turned the creature the other way up (as shown here). However, it is still not clear which is the head and which is the tail.

DETAILED LEG FOSSILS
Trilobites like *Olenoides* were among the most successful arthropods of the time. This Burgess Shale fossil shows *Olenoides*' legs in fine detail, projecting from underneath its hard, crab-like covering.

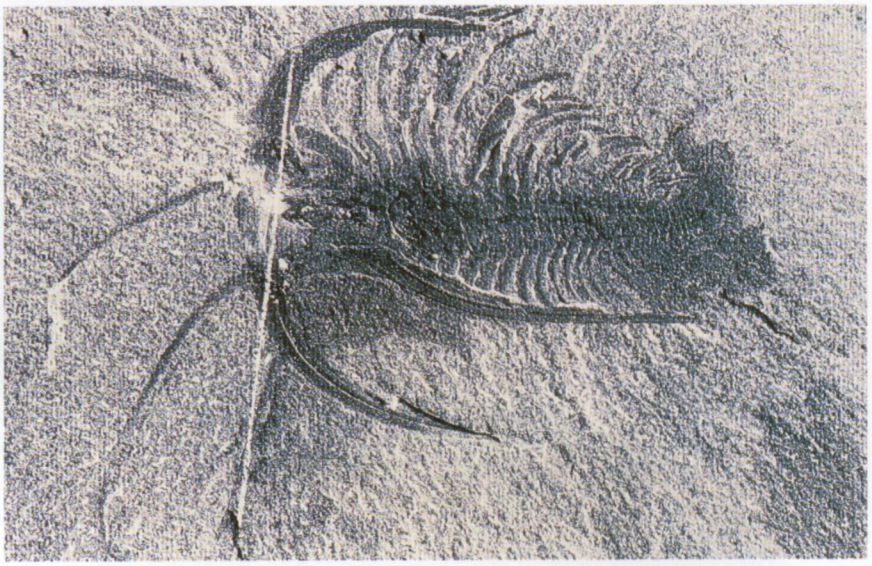
PIKAIA AND THE BURGESS SHALE
The molluscs and brachiopods (two-shelled invertebrates), which appeared during the early Cambrian period, continued to diversify. But perhaps the most important development of this time, at least in retrospect, was the appearance of a small swimming animal called *Pikaia* (see page 66). This was the first animal with the early signs of a backbone, in the form of a long, stiffening rod and spinal nerve cord. *Pikaia* was closely related to the ancestors of all vertebrate animals, including ourselves.

Like animal life, other forms of life were still restricted to the seas. These life forms included blue-green algae (single-celled organisms) as well as early multicellular algal seaweeds (green, red and brown algae).

Information on the creatures of this period has grown enormously since the 1980s. The detailed information from the famous Burgess Shale of Canada has now been supplemented by findings from localities such as Chengjiang in Yunnan Province, China, and Sirius Passet, Greenland.

The Burgess Seaworld

The best picture of the Cambrian seaworld is provided by the 530-million-year-old mudstone of the Burgess Shale in British Columbia, Canada. This site has now yielded thousands of exceptionally well-preserved fossils, many of them completely intact. Taken together, they provide a vivid insight into life in the Cambrian seas at the time when the arthropods were the dominant life form.



SUPERBLY PRESERVED
This *Marrella* fossil is one of many finely preserved specimens found in the Burgess Shale. Antennae, legs and delicate gills are clearly visible. Walcott named this creature the "Lace Crab", but it was in fact a primitive shrimp-like arthropod.

DISCOVERING THE BURGESS SHALE

The American paleontologist Charles Doolittle Walcott discovered the Burgess Shale by chance on August 31, 1909, as he was making his way across a high ridge in the Rockies that connected Mount Field and Mount Wapta. Walcott spotted a profusion of fossils in a block of hard shale and immediately recognized its importance. Not only were the usual hard parts of the animals preserved, but there was also evidence of soft tissue. Walcott had stumbled upon the largest find of almost perfectly preserved fossils from any era.

It is generally thought that the creatures in the Burgess Shale were buried by a mudslide from a submarine cliff. The extraordinary anatomical detail present in the fossils, including delicate appendages, indicates that they were buried rapidly, possibly in mud that was low in oxygen. Without oxygen, tissues decompose more slowly, often becoming replaced by new minerals, and are consequently better preserved.

For eight years after his lucky find, Walcott excavated thousands of specimens, which he then shipped to the Smithsonian Institute in Washington, DC. Work by paleontologists at the University of Cambridge, England, and the Royal Ontario Museum, Canada, has subsequently revealed the full significance of the find.

THE LIFE OF THE BURGESS SHALE

Burgess arthropods had many different lifestyles. The trilobite *Kootenia* lived on the seabed, but *Marrella* was a swimmer. Both ate organic detritus. *Laggania*, similar in form to *Anomalocaris*, was an active swimming predator. Numerous sponges, such as *Pirania*, grew up from the seabed, as did an Ediacaran survivor, *Thaumaptilon*. Many kinds of worms hid in the sediment, including the predatory *Ottoia*. Other worms, such as *Canadia*, lived on the seabed. The mollusc-like *Wiwaxia* ploughed across the mud, protected by spikes and scales. The swimming *Pikaia* is thought to be a vertebrate ancestor. Some Burgess creatures, such as the plant-like animal *Dinomischus*, remain totally unclassifiable.

Laggania

Marrella

Ottoia

Hallucigenia

Pirania

CAMBRIAN SEAWORLD

Study of the fossils found in the Burgess Shale has revealed that approximately 40 different kinds of arthropods accounted for about half of all the preserved animals. A further 30 per cent were echinoderms (the group of which the starfish are members), sponges and priapulid worms. The remainder included brachiopods, molluscs and a curious swimming creature called *Pikaia*, which may be related to living vertebrates.

There were also "hairy" worms living on the surface of the seabed, such as *Canadia* and *Burgessochaeta*. They literally bristled with thousands of tiny hair-like fibres. These bristles, and many of the finely ridged scales and plates of the Burgess animals, are thought to have acted as reflectors to create display lighting. In the dim light that filtered down from the surface of the water, the reflectors and hairs would have flashed silver as the animals moved about, enabling them to recognize each other. These appendages would also have made them visible to predators, but their spines and scales would have defended them.

The wide variety of creatures in the sea at this time suggests that a structured food web, similar to that found in modern marine ecosystems, had already evolved. The discovery of this remarkable diversity so early in evolution, and genetic evidence from living organisms has led to the conclusion that there must have been a lengthy earlier development of multicelled animals, stretching back to Precambrian times.

THREE-IN-ONE ANOMALOCARIS

The most awesome of the Burgess creatures was the free-swimming predator Anomalocaris, *which grew to around 24 inches (60 centimetres) in length. For over 100 years it was known only from fragmentary remains, and these were thought to belong to three quite different animals, a jellyfish, a shrimp and a sponge. Finally, in 1985, it was reassembled as one animal, and named* Anomalacaris. *It looked like* Laggania - *see below.*

IDENTIFICATION
The mouth (left) of *Anomalocaris* was thought to be a jellyfish, the limb (below), a shrimp.

FIERCE WORM
The carnivorous *Ottoia* is one of many priapulid worms found in the shale. They lived in burrows on the seabed and had retractable proboscises with hooks and teeth for grasping their unsuspecting prey.