EDIACARAN GARDEN — 600 MILLION YEARS AGO

Discovering the Ediacaran garden

In 1946, an Australian mining geologist named Reginald C. Sprigg was exploring a range of mountains north of the city of Adelaide, Australia, known as the **Ediacara** (ee-dee-ack-ra) Hills. Serendipitously, he found fossilized imprints of what were apparently soft-bodied organisms, preserved mostly on the undersides of slabs of quartzite and sandstone. Most were round, disc-shaped forms that Sprigg dubbed "medusoids" from their seeming similarity to jellyfish. Others, however, resembled worms, arthropods, or even stranger things. So far these fossils are the oldest significant evidence of animals and thus represent the evolution of the animal kingdom from multicelled protists and bacteria.

These fossils were the first diverse and well-preserved assemblage of Precambrian fossils to be studied in detail, and it helped spark a surge of interest in Precambrian paleontology (the study of fossils of organisms that lived before the Cambrian, which began 540 million years ago, when hard parts evolved). In younger rocks, fossils are more prevalent as a result of, among other things, the easier fossillization of organisms with hard shells or bones. Also, over time, rock layers may be deeply buried, twisted, folded and melted by geologic forces. Such changes to rock would destroy any fossils that might otherwise have been preserved. For these reasons, before the discovery of the Ediacaran garden, many paleontologists held little hope that Precambrian fossils would ever be found.

The Ediacara Hills gave a name to the entire **Ediacaran biota** of the late Precambrian. Appropriately, the name "Ediacara" comes from an Aboriginal language expression meaning "veinlike spring of water" — the "spring," perhaps, from which complex animals have arisen. Officially the **Ediacaran** is the latest (or last) period of the Precambrian from about 650 million years ago to about 543 million years ago. It is within this period of time that the Edicara biota lived.

Since the discovery in Australia, Ediacaran biota have been found at more than 30 localities worldwide on every continent except Antarctica.

			Ages in millions of years (Ma) at period's end
PHANEROZOIC	CENOZOIC	QUATERNARY	0
		TERTIARY	23.8
	MESOZOIC	CRETACEOUS	65
		JURASSIC	144.8
		TRIASSIC	200
	PALEOZOIC	PERMIAN	251
		CARBONIFEROUS	300
		DEVONIAN	355
		SILURIAN	418
		ORDOVICIAN	441
		CAMBRIAN	490
PRECAMBRIAN		EDIACARAN	544
			650
			4000+

What was life like during Ediacaran time?

Bacteria and green algae were common in the seas, as were the enigmatic *acritarchs*—planktonic single-celled algae of uncertain affinity. But the Ediacaran also marks the first appearance of a group of large fossils collectively known as the **Ediacaran biota**.

The question of what these fossils are is still not settled to everyone's satisfaction; at various times they have been considered algae, lichens, giant protozoans, or even a separate kingdom of life unrelated to anything living today. Some of these fossils are simple blobs that are hard to interpret and could represent almost anything. Some are most like cnidarians (jellyfish and anemones), worms, or soft-bodied relatives of the arthropods (crabs). Others are less easy to interpret and may belong to extinct phyla. But besides the fossils of soft bodies, Ediacaran rocks contain trace fossils, probably made by wormlike animals slithering over mud. The Ediacaran rocks thus give us a good look at likely the first animals to live on Earth.

The Ediacaran predates by a distinct interval of perhaps 20 million years or more, the so-called "Cambrian Explosion." Although some scientists believe that many Ediacaran biota might have survived into the Cambrian period, they had vanished without a trace from later fossil records. Some scientists have even suggested that the Ediacaran biota were "failed experiments" in the evolution of multicellular animals. Unlike Cambrian organisms, these odd Ediacaran designs left no descendants.

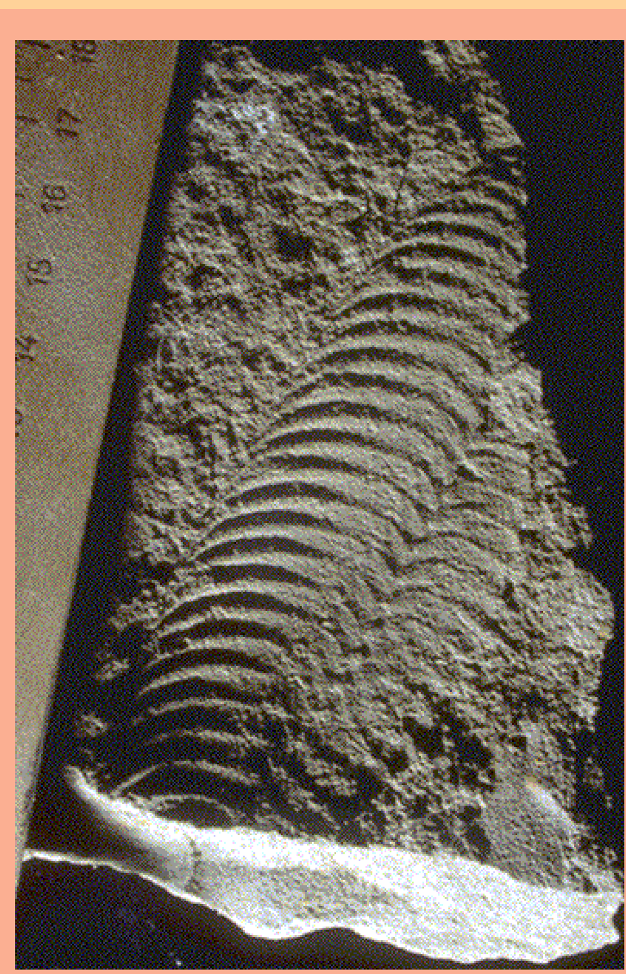
A modern Sea Pen. Some Ediacaran biota were likely early ancestors of this animal.

An artist's depiction of life during the Ediacaran period.

The Cambrian explosion

545 million years ago, at the start of the Cambrian period (end of the Ediacaran), an explosion of diversity led to the appearance of a huge number of complex, multicelled organisms over a relatively short period of 5 to 10 million years. This explosion led to most of the major animal groups we know today, that is, every phylum. Likely many forms that would rightfully deserve the rank of phylum appeared in the Cambrian only to rapidly disappear. Natural selection is generally believed to have favored larger size, and consequently the need for hard skeletons to provide structural support—hence, the Cambrian gave rise to the first shelled animals (such as brachiopods) and animals with exoskeletons (such as trilobites). These fossils appear simultaneously on all continents, except Antarctica, and each assemblage contains roughly the same kinds. Most explanations for this explosion involve properties of animals themselves, but the coincident events in algae and protozoans suggest perhaps a more widespread ecologic trigger. One possibility is oceanographic changes that increased nutrient supplies to the shallow waters. By about 500 million years ago, the rate of evolution had accelerated by an order of magnitude and the diversity of life began to resemble today's.

Two specimens of Kimberella. The fossil on the left is approximately 3 cm across and 9 cm long, while the fossil on the right is roughly 1.5 cm across and 2.5 to 3 cm long. These fossils are preserved on the undersides of siltstone slabs. Note the deep depressions that a rigid shell-like covering made in the silt upon burial. Scientists have shown that Kimberella was a bilaterally symmetric animal that had rigid parts that stood up into the sediment when the animals were buried. Thus, Kimberella appears to be somewhat like a mollusc.



Pteridinium had an elongated, ribbed body that is usually found squashed flat. By examination of numerous specimens we can tell that it was composed of three ribbed "leaflets" that met along the central midline. It probably lay on the bottom, but we do not know whether it fed on small particles, took up dissolved nutrients from the water, depended on symbiotic microorganisms in its tissues, or perhaps used some combination of these ways to feed itself. Exactly what it was, or how it lived, is open to question. Recent research suggests that if it was a cnidarian (jellyfish and anemones), it was not closely related to living cnidarians; it may belong to a group that is now extinct.

Ediacaran fossils from around the world

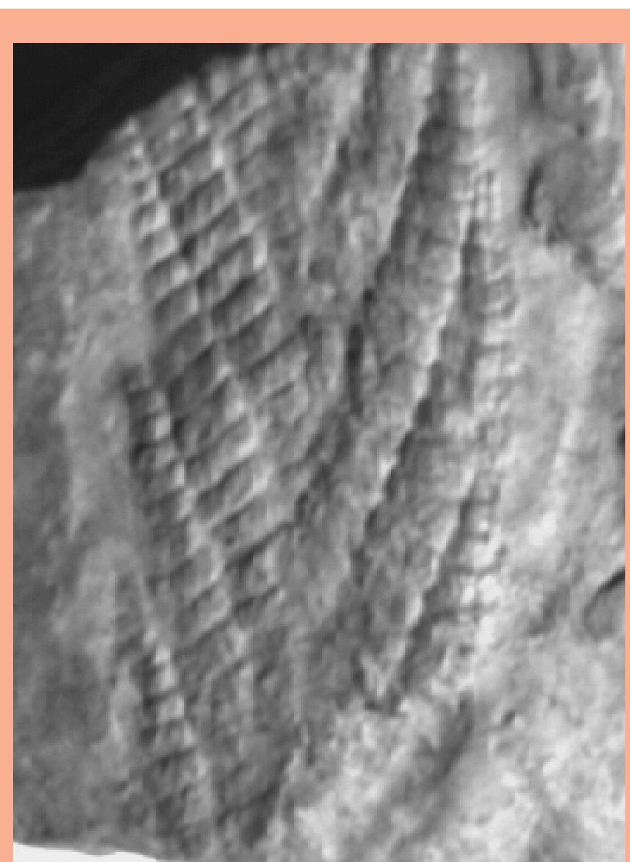
Images from U.C. Berkeley's Museum of Paleontology ©

Cyclomedusa is probably the most common and widespread Ediacaran fossil. It also has one of the largest size ranges, ranging from a few millimeters to about a meter in diameter. Formerly thought to represent a planktonic (floating) jellyfish of some sort, Cyclomedusa is now considered by some to have been a benthic (bottom-dwelling) polyp, somewhat like a sea anemone. It reproduced by division in two or by budding. This specimen is about 5 cm across.

Spriggina is known largely from the Ediacara Hills of south Australia, near Adelaide. The organism had a crescent-shaped head and numerous segments tapering to the posterior end; it is only about 3 cm long. Spriggina was described as an annelid (segmented worm), but it now appears to be related to the arthropods, although Spriggina had no hard parts, and it is unclear exactly what kind of appendages it had.

Eoporpita is one of the most striking Ediacaran fossils, noted for its thick tentacles surrounding a central body. This specimen is nearly 6 cm across. Scientists consider it to have been a benthic polyp rather like a sea anemone.

Dickinsonia is often considered to be an annelid worm because of its apparent similarity to one genus of polychaete, Spinther. However, it may in fact be a cnidarian polyp, like a soft-bodied version of the "banana coral," Fungia. The specimen pictured above is an adult one from the Ediacara Hills of southern Australia.



Charnia is one of the largest Ediacaran fossils, with some specimens reaching 1 m in length. Unfortunately, complete specimens are rare. The flat, leafy body of Charnia was attached to a disk-shaped holdfast that attached the organism to the bottom (not seen on this fossil). Charnia was thought at first to be an alga, but most researchers tend to place Charnia closest to the living "sea pens" or pennatulaceans, a group of colonial cnidarians (jellyfish and anemones) distantly related to the corals.

Few fossils of Ediacaran animals are so compellingly bizarre as this unusual disc-shaped form with three-part (triradial) symmetry. Named Tribrachidium heraldicum, its affinities are still mysterious, although distant relationships have been proposed with either the Cnidaria (corals and anemones) or Echinoderms (urchins and seastars).

Nemiana is one of the simplest of all Ediacaran fossils, and is difficult to interpret. It seems to be an impression of a saclike body. Similar impressions in later rocks and in modern sediments are attributed to sea anemones. Unlike most sea anemones, Nemiana has no tentacles, although occasionally central markings are found that could represent a mouth. Other researchers have speculated that Nemiana might be some sort of large protist, or possibly an alga.

Among the many enigmatic fossils of the Precambrian is an impression named Arkarua adami. The name "Arkarua" comes from a mythical giant snake of the Aboriginal peoples who live where the fossil was discovered—the Flinders Ranges of south Australia, near Adelaide. Arkarua is a small disc-like fossil, and was described as the oldest known echinoderm (seastars, urchins, sand dollars, and cucumbers). The fossils preserve what appears to be a five-lobed central region that is interpreted as five ambulacral grooves, which are characteristic of echinoderms. Unfortunately, the fossils found in sandstone thus far do not preserve any details of the internal organs. No evidence of a stereom or water vascular system is known for Arkarua, and these are considered the diagnostic features for echinoderms, so the identification is still inconclusive.

Header image: Jellyfish from Monterey Bay Aquarium.
Many of the Ediacaran biota are thought to be early jellyfish ancestors. Photo by Francis Parchaso ©