# 2 Endless forms most beautiful

*There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.*

Charles Darwin, *Origin of Species*

If you were to journey back 500-odd million years to the Cambrian and have a walkabout, the familiar landscape would contain few signs of life. On the continents at least, the world had not changed much in the over 3 billion years since life first emerged. The continents equivalent in size to present-day Africa, South America, Australia, Antarctica and India had collided together forming Gondwana, a supercontinent that spanned from the South Pole to the equator. Ice sheets came and went episodically over the pole, but the major icing-overs of snowball Earth were long past and never to return. Global climate was on a warming trend and the continents were fringed by vast shallow seas. It was in these shallow seas rather than on land that the many animals of the Cambrian explosion thrived initially.

You would have had to leave the shore and snorkel or scuba-dive in order to see the many new complex life forms – some fixed to the seabed, others floating or swimming about. Many varieties of red and green algae had diversified in abundance, but brown algae, and more significantly complex plants, had yet to evolve. Many

Living in Cambrian seas, along with existing sponges and jellyfish, were many new animals, including the large anomalocaridids, annelid worms (and other burrowing organisms such as *Ottoia,* front right), the crawling spiked *Hallucigenia* (lower left) and the swimming *Marella* and possibly our earliest fish-like ancestor *Pikaia* (upper left)

algae were still single-celled plankton, while others formed simple colonies or more complex multicellular structures with leaf-like fronds rising up from holdfasts fixed to the seabed. You might see the odd stromatolite dome, but the algae had largely displaced the cyanobacteria at the base of the food chain. The water column was full of living and dead bits of algae, which were being filtered out and consumed by a variety of long-existent sponges. Also present were the survivors among the Ediacaran animals, mostly jellyfish and simple corals. What was strikingly new about Cambrian seas was their diverse community of animals. Some scavenged food as they crawled along the seabed; some devoured others while darting about in the water column. These were the first of the bilaterian animals, which had previously featured in only a minor way but now came into their own.

Among the newcomers were some with unusual body shapes and structures: the 2-metre-long anomalocaridids, the multiple-eyed *Opabinia* with its long feeding appendage, and *Hallucigenia* walking about on tube-like legs and covered in protective spikes. Descendants of the Ediacaran bilaterian fossil *Kimberella* may have evolved into the first shellfish (brachiopods and molluscs) and furrowing Ediacaran bilaterian organisms may have evolved into the first worms. However, the origin of most

*Hallucigenia*

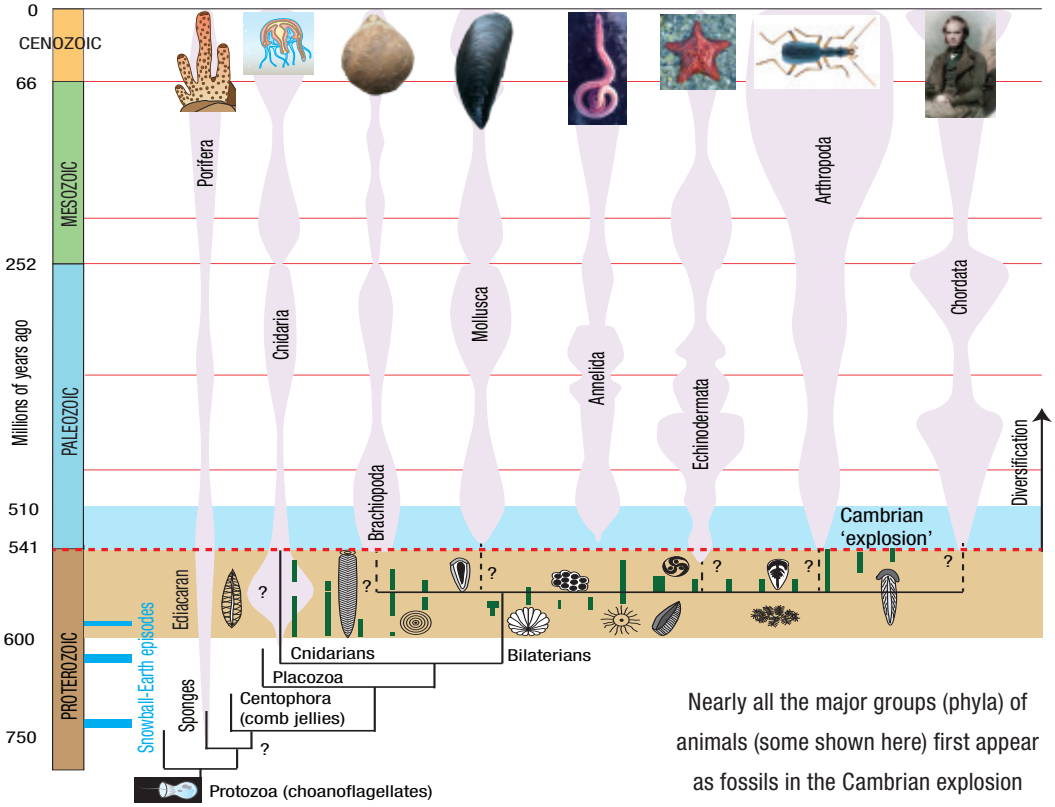
*Opabinia*

Cambrian animals remains obscure. What we do know is that 99% of all animal groups living today made their debut in the fossil record during the Cambrian explosion.

## The Cambrian explosion

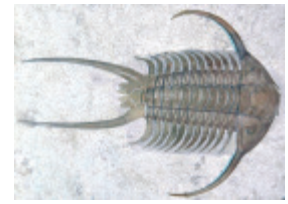
The many new Cambrian animals didn't all arrive at once: most took time to evolve and continued to diversify throughout the Cambrian. So the Cambrian was not as 'explosive' as originally thought, but unfolded over the 70 million years commencing near the boundary at 541 million years ago and continuing into the early Ordovician period up until around 470 million years ago. Nevertheless, it was a period of major evolutionary innovation relative to the billions of years leading up to it. It was when all the existing basic body plans of bilaterian animals first appear in the fossil record.

Similar to a floor plan of a building, a body plan is how the parts of an animal are organised and structured. All living and fossil animals can be assigned to a group, called a phylum, on the basis of their body plan. Biologists define a total of 30-odd different phyla into which the members of the animal kingdom can be placed. We belong to the phylum Chordata, and along with all other animals possessing a backbone we belong to the chordate subphylum of vertebrates. Not all chordates



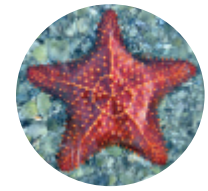

Nearly all the major groups (phyla) of animals (some shown here) first appear as fossils in the Cambrian explosion

have a backbone but they all have, at some stage of development, a notochord – the cartilaginous rod that runs down their back associated with nerve fibre bundles.



Trilobite

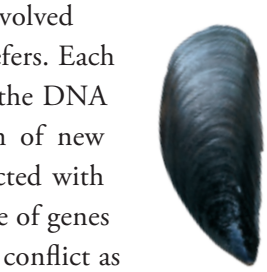
The phylum Arthropoda, to which the extinct trilobites and all living insects belong, is defined by segmented bodies having paired jointed limbs and an external hard cover (exoskeleton). The phylum Echinodermata includes sea stars and sea urchins, and is defined by its distinctive five-fold (pentaradial) symmetry. The phylum Brachiopoda includes marine shelled organisms (lamp shells) whose upper and lower shells are different in size or shape but each is bilaterally symmetric. In contrast, the line of symmetry defines identical left and right shells belonging to bivalves (clams and mussels) in the phylum Mollusca. These are just a few examples of the many distinct body plans that evolved during the Cambrian explosion.



Sea star

The interpretation of the many early animals of the Cambrian explosion has varied over the years, but it is now thought that as bizarre as some may look to us today they can all be assigned to existing body plans. Although these basic animal body plans have not changed – no phylum has become extinct and no new phylum has appeared – there have been many evolutionary innovations within each phylum since the Cambrian. It is to these variations, the amazingly diverse forms of life that have evolved since the Cambrian, that Darwin's 'endless forms most beautiful' refers. Each phylum rapidly gave rise to its own finely branching tree of life as the DNA within each was passed on in modified form with the evolution of new species. The animals of the various trees co-evolved as they interacted with and influenced one other to varying degrees, but the direct exchange of genes was restricted to closely related species. Some interactions included conflict as individuals competed against members of their own and other species for limited resources in an ever-escalating arms race between predator and prey. Other interactions included cooperation as species developed mutually beneficial relationships (symbioses). Species came and species went: in fact, an estimated 99.9% of all the species that ever lived are now extinct. But all the estimated 5 to 10 million species living today, including us, owe their existence to a long chain of descent by way of many ancient, now extinct, ancestors.

Lamp shell



Black mussel closed (top) and opened (bottom)