# Cambrian Explosion

The modern phyla of multicellular organisms show up in a "flash" at the beginning of the Phanerozoic Eon (which is also the start of the Paleozoic Era and the Cambrian Period).

**545 Mya** marks the first appearance of complex, sediment-penetrating trace fossils
Implication: Big animals with coeloms are on the scene. Yet they must have been soft-bodied, as we don't have a good body fossil record from this interval.

***More on Trace Fossils of the Cambrian***

The Cambrian Tapeats Sandstone occurs in the Grand Canyon in Arizona.
The half a billion year old sediments represent tidal flat and near shore deposits during a time when primitive metazoans ruled the earth.
The Tapeats contains a few trace fossils, include **Corophioides**
The Corophioides are the dwelling traces of a large U shaped annelid worm which lived beneath the sediment surface.

**~ 530 Mya** Small-shelly fossils begin to appear in the record
The shells exhibit a range of mineralogies
Coiled snail shells were present, indicating that the Phylum Mollusca had appeared.
Sponges spicules and the extinct sponge-like Phylum **Archaeocyatha** were present.
Many of the shelly fossils are difficult to relate to any modern group.
Recently, fossilized embryos have been reported from this interval

***Archaeocyatha***

Archaeocyaths are an extinct group of sponges that had a very brief history.
The first appear roughly 530 million years ago
Diversified into hundreds of species during this time period, with some species contributing to the creation of the first reefs.
Despite their great success in terms of numbers, the archaeocyaths were a short-lived group

**~ 525 Mya:** Begin to find larger shelly fossils

***Trilobites**:*

Trilobites were among the first of the arthropods
Probably descendents of segmented worms; developed hard exoskeletons, eyes and the ability to grow by shedding their old shells

Trilobites were a dominant life form during much of the 325 million years of the Paleozoic.
Trilobita, made up of eight orders, over 150 families, about 5000 genera, and over 15,000 described species.

With such a diversity of species and sizes, speculations on the ecological role of trilobites includes planktonic, swimming, and crawling forms, and we can presume they filled a varied set of trophic (feeding) niches, although perhaps mostly as detritivores, predators, or scavengers.

**Brachiopods** appeared as well about 525 mya
Brachiopods are marine lophophorates and are related to the Bryozoa and Phoronida.
Brachiopods are filter-feeders which collect food particles on a ciliated organ called the lophophore

Brachiopods are divided into two major groups
Class Inarticulata (including lingulids), and Class Articulata based on the presence or absence of hinge teeth and sockets.

Several strange groups of **echinoderms** (e.g., eocriniods, helicoplacoids) are known from this age (~525 mya) as well.

***Eocrinoidea***

Eocrinoids are among the earliest groups of echinoderms to appear, ranging from the Early Cambrian to the Silurian.
Most eocrinoids were sessile and fed with their long **brachioles** (the arm-like structures, which in this specimen are spirally twisted).
The body was covered by plates; in early eocrinoids the holdfast was also covered by plates, but later eocrinoids evolved a stalk with columnals, like crinoids and blastoids.

***The Helicoplacoidea***

The Helicoplacoidea is a small group of fossil echinoderms known only from the Lower Cambrian.
Shaped somewhat like a slender football ad were presumably able to extend or contract the length of their bodies.
Their "skin" was covered in spirals of overlapping **ossicles** that functioned like armor; their "mouth" was a long groove that also spiralled around their body.

It is thought that helicoplacoids lived in burrows, extending their bodies outward to feed.

The **reefs** of the time period were composed of archaeocyathids. (extinct animals related to sponges)

***Summary***

So, in a mere 20 million years, nearly every major of fossil forming metazoan has appeared on the planet
<u>Note</u>: There are many phyla of metazoans that don't make mineralize skeletons.□
Q. Was the Cambrian an explosive time for them as well?□

**~ 525 to 515 Mya:** Burgess Shale and similar deposits

Discovered by Walcott in 1909.□
The Burgess shale is located high in the Canadian Rockies
Fossils from the site have been collected and studied by a number of groups, and new Burgess-type localities have been discovered along the west coast of North America, and in eastern North America, Greenland, and (most spectacularly) China.□

**Some of the Burgess animals fit nicely into extant phyla of soft-bodied (and shelly) animals such as:**

The branching sponge ***Vauxia*** was one of the most common sponges encountered by Wolcott

***Polychaete annelids***

***Canadia spinosa* -** these annelids, about 1 to 2 inches in length, are some of the most photogenic of the Burgess Shale fossils.

The head bore a pair of slender tentacles while the body was covered with innumerable setae (short bristles).
The gut could be everted anteriorly to form a feeding proboscis. ***Canadia*** could use its limbs to walk on the substrate or swim just above it.
Sediment has never been found in the gut, suggesting that this worm may have been a carnivore or scavenger.

***Priapulid worms***

Quite a number of fossils of the carnivorous priapulid *Ottoia* have been found in the Burgess Shale.
In fact, priapulids and arthropods are the most common complex animal fossils from this Cambrian locality, and make their appearance in the fossil record as early as most of the first-known members of various major animal groups.
*Ottoia prolifica*, probably lived in a U-shaped burrow that was constructed in the substrate.

***"Arthropods"***

*Marrella splendens* is a small "arthropod" somewhat reminiscent of a trilobite, but with several distinctive features
*Marrella* is one of the most common fossils in the Burgess Shale, and was probably the first soft-bodied organism noticed by Walcott

**Some Burgess animals are quite strange, and are difficult to associate with modern groups:**

***Wiwaxia***

Longer spines project in two rows along the back, and evidently provided some protection from predators.
The rest of the upper (dorsal) surface is covered with small, flat, overlapping hard plates, termed sclerites.
Each of these little scales was attached with a root-like base and we assume *Wiwaxia* grew by molting these plates from time to time.
Since there are none on the bottom (ventral) surface, the animal partly resembles the slug, a member of the mollusk family.
However, mollusks do not have any sclerite armor so the animal's affinity to present day species is unsettled.
It did have an anterior jaw with two rows of teeth on the ventral surface, suggesting it was another bottom feeder. Fossil sizes range from 1/8 to 2 inches.

***Anomalocaris***

Probably the largest animals of the Cambrian Era, about 60 cm long.
*Anomalocaris* had a long, oval-shaped head, large eyes, feeding appendages at the front that look like combs, and a circular mouth underneath.
Behind the head a "trunk" extended, which took up most of the length of the *Anomalocaris*, and had lobes underneath it in pairs which enabled it to swim.
Since the *Anomalocaris* has no legs or walking appendages, it probably swam all the time, using these lobes.
The mouth of *Anomalocaris* species was located on the front end of the head, underneath.
It was round and cylindrical, with many tiny teeth facing inward.
Food was brought to the mouth via the feeding appendages, which would capture food and curl up, bringing the food to the mouth.

***Dinomischus***

*Dinomischus* was a wine glass shaped animal, measuring about one inch long.
It had a bulb at the base of its stem to secure it in the mud.
On its circular upper surface, surrounded by petal-like bracts, was a mouth and an anus.

***Opabinia***

A creature with five eyes and a long flexible proboscis tipped with grasping spines
The proboscis could have plunged into sand burrows after worms.
It also possesses paddle-like projections at the posterior end of the body.
Sizes ranged up to 3 inches, plus that unique, amazing 1-inch proboscis!

*Opabinia* is thought to have lived in the soft sediment on the seabed, although it presumably could have swum after prey using its side lobes.
Superficially, *Opabinia* resembles a crustacean

**Some Burgess animals seemed odd at first, but upon further study appear to be related to modern groups:**

***Aysheaia***

Possesses an unusual assembly of spines and grasping arms at the head end.
Its mouth lies in the center of a ring of six finger-like projections.
The limbs of this animal are not jointed; instead, they are tapered, lobe-like appendages, ten pairs in all, projecting from the body with its set of small rings or annulations.
*Aysheaia* may have been a parasite living on sponges since it is commonly found in association with spicules

***Hallucigenia***

Based on the appearance of initial fossil preparations, the first restoration made in 1977 presented us with an animal walking along the bottom on spiny stilts, waving 7 dorsal tentacles from its back.
Not only that, those tentacles on the "back" seemed to have a mouth at each tip, and were believed to be the feeding aids.

Recent findings of exceptionally well preserved specimens of an animal indicate that there was a second set of tentacles opposite the spiny projections, each tipped with a set of claws.
The spines probably were not used for walking; instead, they may have protected the back of the animal (like *Choia* or modern-day sea urchins), while the clawed tentacles were the real walking legs!

**Finally, Burgess-types deposits yield yet another of the important fossil-forming groups: the Chordates**

***Pikaia***t is believed to be one of the earliest known representatives of the phylum Chordata
It has a well-defined notochord near the dorsal surface.
Also possesses rib-like features which are believed to be muscles.
Averaging about 1 1/2 inches in length, *Pikaia* swam above the seafloor using its body and an expanded tail fin.

□

## Explanations for the Cambrian Explosion

### Environmental Explanations

***Ocean Chemistry***
Change in ocean chemistry to allow shells.
Doubtful, given the range of shell types that appeared?

***Soft-bodied Bias***
An apparent explosion, due to the strong bias against finding soft-bodied forms?
Doubtful (or is it)□Remember, there aren't even trace fossils suggesting large coelom-bearing metazoans were present before 545 Mya.

***Change in Oxygen***
Sudden oxygen buildup that allows big bodies and perhaps skeletons.□
Maybe.□There is strong geochemical evidence for higher oxygen levels at the Proterozoic-Cambrian boundary.□
It may be that bigger bodies just weren't possible prior to this point.□

Perhaps coelom-bearing metazoans are present back in the Proterozoic, but they are small and floating or swimming, up off the sediment water interface.□
Alternatively, it may be that the rise in oxygen triggered a sudden evolutionary event.

***Positions of Continents***
The position and configuration of the continents were also undergoing major changes
Between 750 and 570 mya, the continents were grouped toward the South Pole and there were several episodes of continental glaciation effecting many areas of the world
However, this was soon followed by movement of the continents away from one another
These resulted in higher temperatures and an increase in coastline and continental shelf, augmenting the right conditions for marine life

**Biotic Explanations**

***Arms Race***
Some workers have argued that the rapid diversification may relate to a predator/prey arms race.□
Predation would certainly favor animals with skeletons.

***Hox Genes***
Evidence from development biology indicates that the rapid development of complex body plans, with many distinct cell types and anatomical structures can occur through the action of ***Hox* genes**
*Hox* genes are unique to metazoans and evolved from a more inclusive group, the **homeobox genes,** that code for specific proteins that activate other genes, and thus they regulate a host of processes within the cell

*Hox* genes are uniquely arranged in a linear sequence along the chromosome, which corresponds with both the linear and the temporal sequence of their activation along the anterio-posterior axis of the embryo

The number of *Hox* genes arranged in a cluster along a chromosome is broadly comparable to the degree of complexity of the organism

These genes control the position and the expression of major structural features of the body, including the elements of the head and the sequence and nature of the appendages
*Hox* genes act as switches to control the expression of a variety of genes, which in turn control different structures and cell types

The origin of multicellularity and complex body plans among animals was a unique phenomenon, dependent on the evolution of *Hox* genes near the end of the Precambrian
Once evolved, their subsequent duplication and divergent change in adaptively distinct lineages established the basis for the radiation of the many metazoan phyla

Interestingly, most phyla have apparently retained a relatively constant number of *Hox* genes since the Cambrian
Also, we can recognize a hierarchy of change associated with *Hox* genes between and within phyla

In summary, changes in the number of *Hox* genes and their control over expression of other genes can explain how distinct body plans and appendages evolved in the Precambrian and Cambrian
Furthermore, they provide a basis for explaining other structural changes observed throughout the subsequent history of life.
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