

EXTINCTIONS: PAST AND PRESENT

UNIVERSITY OF CAPE TOWN



WEEK 1 FROM SIMPLE TO COMPLEX

All life on Earth is related. In fact, we can divide all life into three domains: bacteria, archaea and eukaryotes. Bacteria and archaea are unicellular and they lack a cell nucleus as well as internal organelles. Eukaryotes, on the other hand, are everything else. They include plants, animals, fungi, as well as protists. They have a nucleus and they have complex internal structures such as organelles. Although bacteria and archaea may look alike, DNA studies have shown that archaea are more closely related to eukaryotes.

In the fossil record the oldest records of life appear to be microbial. In the 3.5 billion year old rocks from Barberton in South Africa, scientists have discovered carbon traces along the walls of tiny tubes that are suggestive of microbial life. The definitive oldest life on Earth are stromatolites from East Strelley Greenstone. This is in Western Australia, and they date to about 3.5 billion years. Stromatolites are formed by aggregates of cyanobacteria. These are single cells that have acquired the ability to have photosynthesis. Cyanobacteria are really very important in Earth's history. We generally suspect that early Earth lacked oxygen. It is currently hypothesised that the oxygen in the atmosphere was a by-product of photosynthesis of cyanobacteria. The presence of oxygen in the atmosphere can be traced by looking at rocks that were formed at around the same time. We see clear evidence that oxygen in the atmosphere would have dissolved in the water and reacted with iron to form iron oxides that formed distinctive bands in marine rock.

In central Australia the Bitter Springs chert formation has preserved an incredibly well diverse flora of microorganisms. These date to about 850 million years ago. In these deposits there are about 30 different kinds of microbes preserved. They include cyanobacteria as well as fungi and dinoflagellates. In this site even eukaryotes, that is cells with nucleus and organelles, are found. This is a major advancement for life on

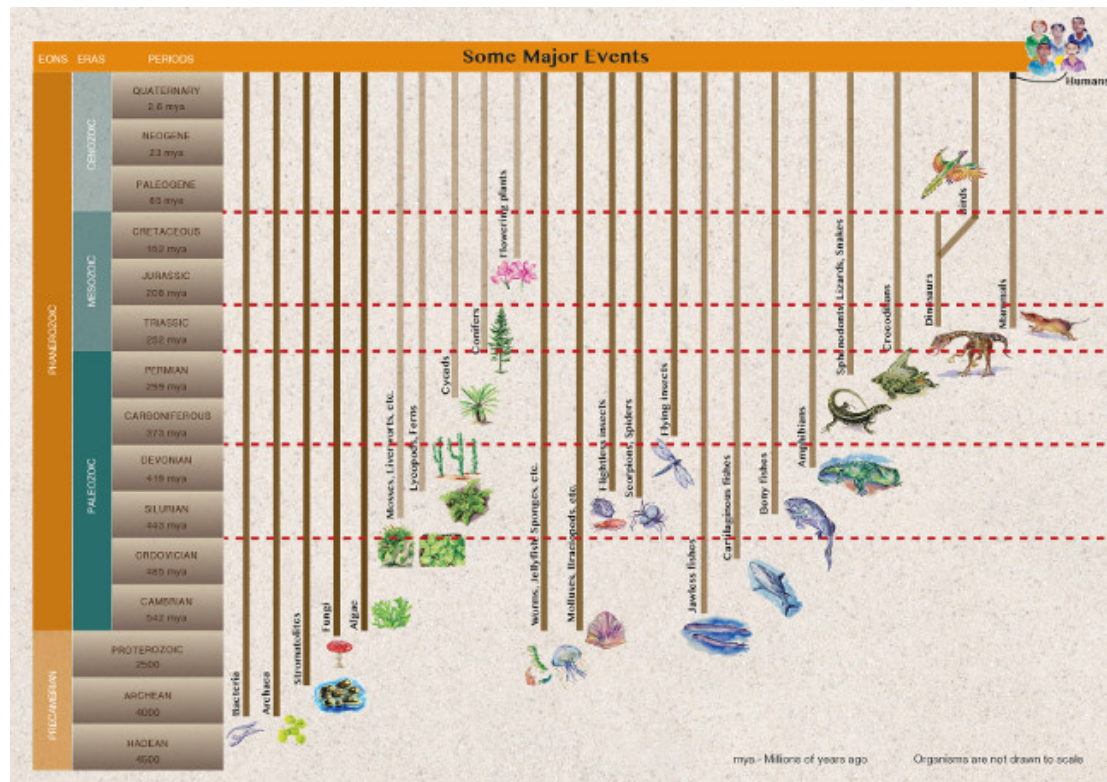
Earth. It is interesting to note that there are few places in the world where you can still see living colonies of cyanobacteria. For example, you can find them in Hamelin Pool and in Shark Bay in Australia.

The next major step is when life becomes multicellular. For a long time we had fossils that dated to about 575 million years ago, that showed this. But more recently fossils from Gabon in west Central Africa, suggested that this may have already happened at 2.1 billion years. Using microtomography scientists have shown that these fossils have complex external, as well as, internal structure. The ten centimetre long branching tubes of Grypania from Michigan also suggest that multicellular life may have developed much earlier than previously supposed. Indeed, there are also sponge-like body fossils from Namibia that date to about 760 million years that also support this idea. Undisputed multicellular organisms date to 575 million years ago and they are often referred to as the Ediacaran fossils. Most of these fossils show soft tissue impressions of what appears to be organisms with complex organisational structure. We're not really sure exactly how they looked since they are often compressed and found in 2D, but usually the information recovered from the fossils allow artists to make reconstructions of what the ecosystem may have looked like.

The Burgess Shale formation dating to about 542 million years ago occurs in the western Canadian Rockies and it is an incredible site since it is witness to one of the most dramatic steps in the evolution of life on Earth. We see here, within a relatively short space of time, an explosion of diversification. All extant phyla are present within five to ten million years. Several complex soft-body organisms are found but we also find algae and relatives of arthropods such as trilobites. These are very interesting animals which have a hard outer skeleton and their bodies are divided into three lobes. We also begin to see organisms with internal skeletons at this time. One of the largest predators known from the Burgess Shale is a two metre long Anomalocaris, seen here in a reconstruction by Luis Rey chasing down trilobites. Trilobites are an extremely diverse group. They have extravagant spikes and horns projecting from the exoskeletons and in some cases even the eyes are preserved and we know today that they have compound eyes like insects but their lenses are made of calcite. There are also diverse brachiopods that occur. Molluscs are abundant in the fossil record from this time onwards and we find many different kinds of mollusc present. So are crinoids which are commonly known as sea lilies because of their long

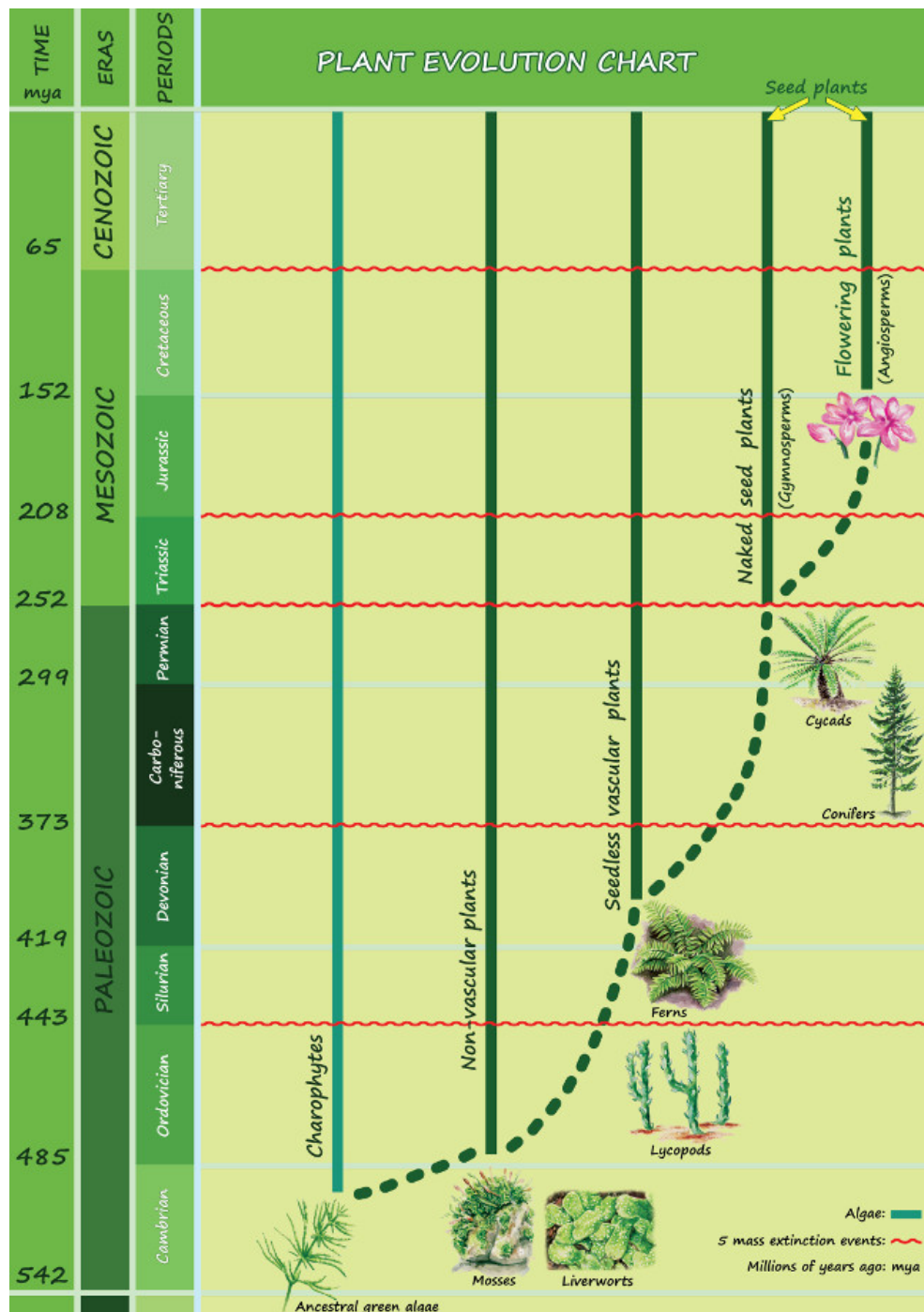
stems but they are not plants, they are echinoderms related to starfishes. If we look at this history of life chart we can see where in the fossil record the ancestors of many of the modern groups originate.

History of life chart



It is clear that already by the Cambrian we had a rich, diverse biota on Earth. Spores of the earliest land plants called cryptospores are known from Argentina dating to around 473 million years ago. A 360 million year old fossil locality near Grahamstown in South Africa has given us an exceptional window into life at this time. In these deposits we see octochara, a charophyte which is considered to be the ancestors of land plants. This site also gives us an idea about the early diversification of plants. For example, we see some very simple lycopods, as well as Leptophloem, a tree-like lycopod, and Archaeopteris, from this site.

This chart shows the evolution of plants and we can see how plants became increasingly complex over time. In the Permian, glossopteris forests were abundant but after the end of the Permian extinction event we see a diverse array of Dicroidium. And we have many, many wonderful fossils that show this incredible preservation of this biota.



Many examples of plant, insect interactions are also represented in the fossil record and in many plant localities insects are also very well preserved. Insects are known in the fossil record from about 400 million years ago and it is quite possible that they evolved even earlier since the earliest insect fossils have wings already.

Here we see *Afrocupes*, the oldest beetle known from Gondwana. It dates to about 300 million years. One of the earliest land animals known from Gondwana is an arthropod, in fact a scorpion called *Gondwanascorpio*.

If we look at the history of life chart we see that the earliest vertebrates occur in the fossil record from about 550 million years ago.

Here is a picture of *Metaspriggina* from western Canada which dates to 500 million years ago. You can clearly see it looks rather fish-like but it did not have teeth neither did it have bones or paired appendages. These structures developed later.

From Waterloo Farm near Grahamstown in South Africa we have one of the only Gondwanan jawless fishes known. This is a fossil lamprey called *Priscomyzon*. This 42 millimetre specimen is the most primitive vertebrate found in Africa and it also the oldest lamprey in the world. Fish with jaws developed towards the end of the Ordovician and soon we get a diverse array of armoured fish, the placoderms. From Waterloo Farm we have several examples of placoderms. Here we see a reconstruction of *Groenlandaspis* with two lampreys feeding on it and a school of deep-bodied acanthodians, called *Diplocanthus*, going by.

Cartilaginous fish are known in the fossil record from Devonian onwards and from Waterloo Farm we have a tiny baby shark measuring just about 23 millimetres. Bony fish radiation is a very important one. They are found from the Devonian onwards. Here we see an example of mass mortality of ray-finned fishes from a site near Port Elizabeth in South Africa. Amongst the bony fishes there is a group of fish called the lobe-finned fish. Amongst these we have the ancestors of tetrapods.

Next week we're going to talk about the radiation of the tetrapods. It should be clear to you that although life on Earth began as simple unicellular forms, over time, life became increasingly complex and more and more diverse.



Anusuya Chinsamy-Turan 2017

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