What's a Million Years between Friends?

David Alexander Lillis 2019

A Period in the Evolution of Man

Most of us these days accept that life has followed some kind of evolutionary process that has played out over a very long period of time. However, getting our heads around the enormous lengths of time available for the evolution of life is next to impossible, even for those who work in relevant scientific fields.

We talk of 300,000 years or more since the emergence of *Homo sapiens*, 700,000 years since the common ancestor of Neanderthals and ourselves, over 1.8 million years since the time of *Homo erectus*, and 1.9 million years since *Australopithecus sediba*, possibly one of the last australopithecines.

Skull of *Australopithecus sediba*. Photograph from Professor Lee Berger.

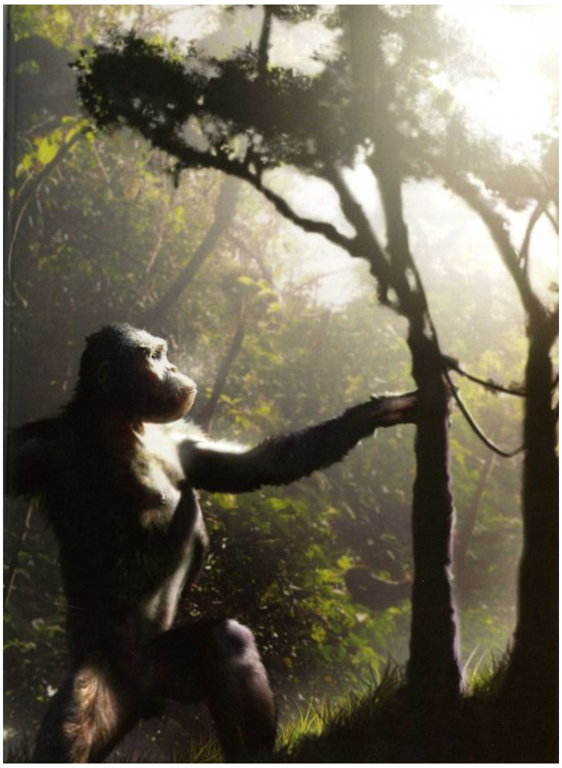
It's approximately 3.2 million years since Lucy, a member of *Australopithecus afarensis*, lived out her life, and approximately 6 million years since *Orrorin tugenensis*, an ancestral hominin that ultimately may (or may not) have given rise to ourselves.

Lucy – a member of Australopithecus Afarensis (image from Phys Org)

A single million years is a very long span of time indeed for a human and it's nearly impossible to comprehend. A species can evolve, live out its time and become extinct within a single million years. However we decompose it mentally (e.g. a hundred times ten thousand years or ten periods of a hundred thousand years), it's very hard to imagine. How much more difficult it is to imagine tens or hundreds of millions of years!

Sometimes it can help to think in terms of numbers of generations. Greshko (2017) tells us about early *Homo sapiens* who inhabited what is now Morocco between 300,000 and 350,000 years ago. If each generation is separated by an average of 20 years, that's approximately 15,000 generations or more. Place yourself at the head of a queue and walk past your mother, grandmother etc, each separated by one meter, and you must walk for at least 15 km.

You must walk for at least 35 km - 40 km to reach the common ancestor of Neanderthals and ourselves (approximately 700,000 years ago). Probably you will want to borrow the family car to travel the 120 km (assuming an average of 15 years per generation) needed to visit *Homo erectus*, 130 km to visit *Australopithecus sediba*, and the 210 km or more to catch up with Lucy. Certainly, you will prefer to use a jet to get back to that original hominin, *Orrorin*, who is at least 500 km away. Of course, *Orrorin* has ancestors that go much further back in time.



Orrorin tugenensis (image from Viktor Deak)

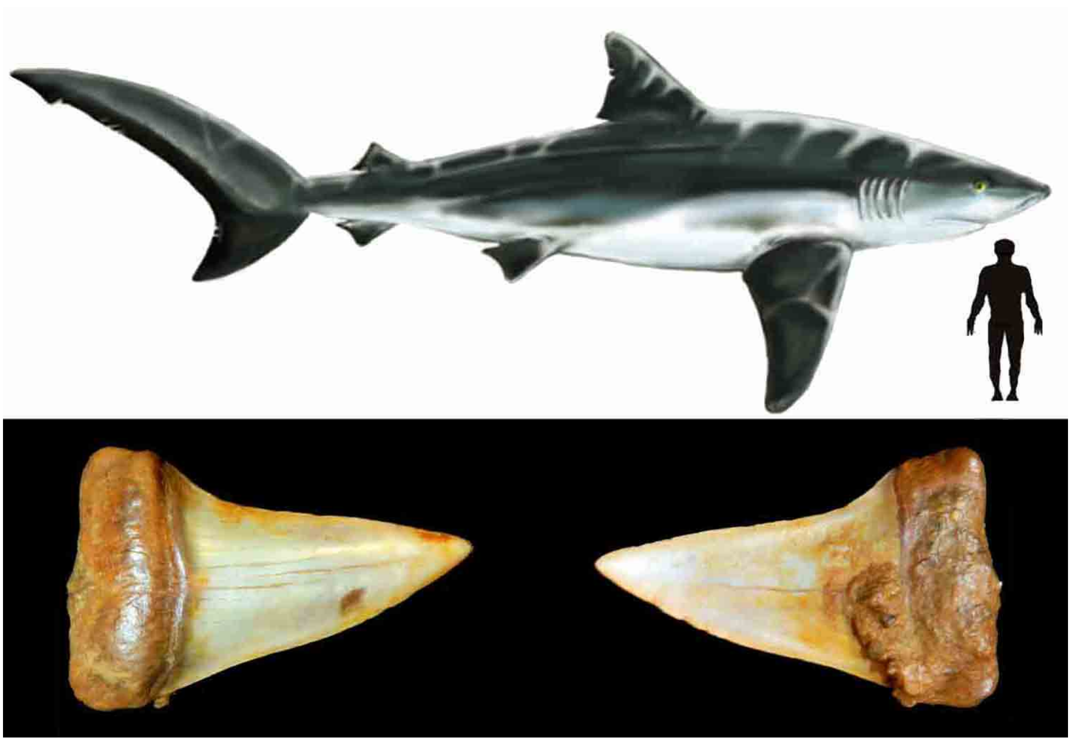
Giant Sharks and Dinosaurs

I own a fossil tooth from *Carcharodon megalodon*, found on a beach in North Carolina and dated at approximately 16 million years. Since this animal is extinct and has left no direct descendants, we should no longer talk in generations but, if we place a stake in the ground for each year at one meter intervals, we need a jet to travel the 16,000 km to see that fish. The Cretaceous extinction, at 66 million years ago, is now 66,000 km away, approximately one sixth of the distance to our moon. Our fastest passenger jets (flying at approximately 1000 km/hr with a good tailwind) will take 66 hours to get there. You will have to fly continuously for 180 hours or more to cover the distance of about 180,000 km from the earliest dinosaurs, such as *Nyasasaurus parringtoni*, at 243 million years (Black, 2012),to the last of the dinosaurs at the very end of the Cretaceous.

Nyasasaurus parringtoni (from http://dinosaurpictures.org/Nyasasaurus-pictures)

Evolution of the White Shark's Teeth

Viegas (2012) writes about the evolution of the great white shark, possibly descending from a family of mako sharks of approximately 10 million years ago. Over that period, the ancestral great whites evolved from primarily fish-eaters (that also predated on pinnipeds and other marine mammals) to predate increasingly on pinnipeds (seals and sea lions) and dolphins. At about five years per generation, that's about two million generations to evolve from mako-like sharks, such as *Carcharodon hastalis* (which lived from approximately 20 million to approximately 3 million years ago), to the modern great white.



Carcharodon hastalis and its teeth (Illustration from: https://www.larcadinoe.com/fossils/fishes-and-sharks/chondroichthyes-sharks/isurus-hastalis-3-tooth)

National Geographic (2012) tells us that today's great white sharks are probably modified broad-tooth makos, and the giant shark, *Carcharocles megalodon*, is a member of a subgroup that separated from the great white lineage during the Cretaceous (i.e. the separation occurred 70 million years ago or more and thus the megalodon and the modern great white are not as closely related as previously thought). It also tells us that the triangular teeth of *Carcharodon hubbelli* (an ancestral white shark from Peru, approximately 4.5 million years old) are not quite as serrated as those of the modern great white shark, but are considerably more serrated than those of *Carcharodon hastalis*. At about five years per generation, the slight increase in serration of the modern great white teeth over those of *Carcharodon hubbelli* has taken approximately 900,000 generations to evolve.

Fossilised jaws and teeth of *Carcharodon hubbelli* (Florida Museum; photograph by Geoff Gage)

It seems that the modern white shark tooth evolved over many millions of years from a primarily fish-eating tooth to its modern form - perfect for eating marine mammals!

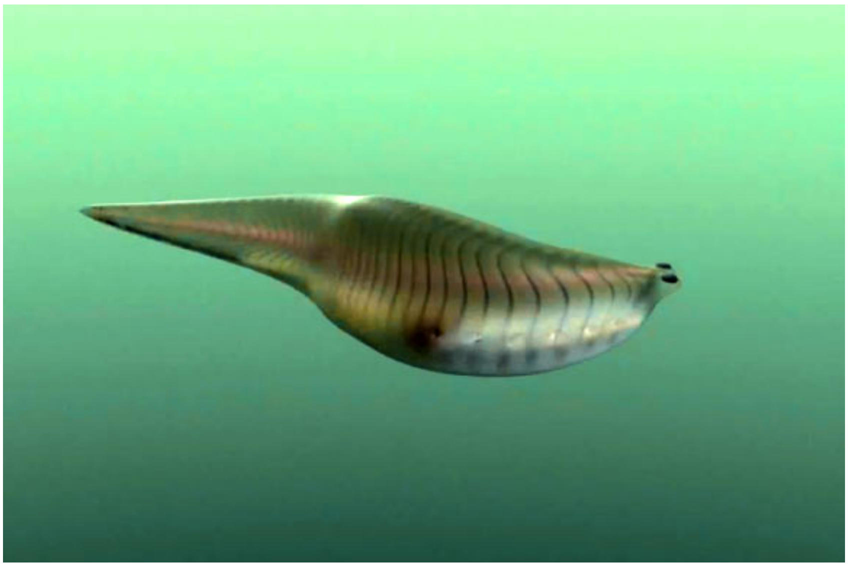
Carcharodon hubelli (Florida Museum illustration by Jason Bourque)

The Emergence of the First Life on Earth

Prokaryotes may be the first living things on Earth. They were single-celled organisms that did not possess a cell nucleus or cell membrane and may have evolved almost four billion years ago. A jet is no longer of any use if we are to travel back to see those early prokaryotes. If our jet travels at 1000 km/hr, then it would cover 8,760,000 km in a year. Our journey to see the Prokaryotes would take us 457 years.

The Emergence of Fish, Insects and Mammals

The earliest fish ancestors such as *Metaspriggina walcotti* (The Conversation, 2014) may date as far back as 560 million years. We could visit them by jet if we were patient enough to travel for 64 years.



One of the earliest fish ancestors: *Metaspriggina walcotti.* Sci News. Image by M. Collins.

The earliest insects may have evolved as far back as 479 million years ago (Palermo, 2014). We could reach them by jet in 55 years and we could reach the earliest true mammals of approximately 200 million years ago (Bryant, 2002) in 23 years.

The Times of Extinction Events

In addition to the relatively gradual extinction of a species through natural competition, disease or climate change, we have records of mass extinctions through geologic time. Some of these extinctions are thought to have been partly or wholly caused by rapid climate change, while the last major event of 66 million years ago (the K/T event) probably was caused by a meteorite impact near the Yucatan Peninsula, Mexico. Our fossil records show that extinction of dinosaurs, marine reptiles, ammonites and other animals and plants species occurred at the boundary between the Cretaceous and the Paleogene epoch (K/Pg boundary). We find evidence in deep-sea cores of marine mud and other strata now on land, where the disappearance of many species of marine plankton occurs precisely at the K/Pg boundary (Vadja et al, 2001; Hollis, 2003a; Hollis, 2003b, Taylor et al, 2018). New Zealand-based work shows that the impacts of this event for the Southern Hemisphere were as severe as in the Northern Hemisphere (GNS Science, 2012).

A thin layer of clay found at boundary sites around the world contains extremely high amounts of elements, such as iridium, that are rare on Earth but abundant in meteorites. This boundary clay also contains impact-shocked mineral grains and droplets of impact glass. All of the dinosaurs, marine reptiles and many other species vanished at that time, and approximately 76% of all species were lost. We must fly for over 7.5 years in our jet to see the last of the dinosaurs and their extinction.

Richter (2019) gives an informative account of the other main extinctions, as follows:

1. An event occurred at the end of the Triassic, approximately 200 million years ago, when approximately 80% of species became extinct. We need 23 years to get there in our jet.
2. A major extinction occurred at the end of the Permian (possibly triggered by volcanism), about 251 million years ago, when approximately 96% of species disappeared. We need 29 years to get there.
3. Another event occurred in the Late Devonian (possibly also triggered by glaciation), 375 million years ago, in which approximately 75% of species vanished, requires 43 years in our jet.
4. An event occurred at the end of the Ordovician (possibly triggered by glaciation), about 444 million years ago, when approximately 86% of species became extinct. We must spend 51 years in our jet to see that event.

Of course, after these events the extinction of many species provided opportunities for others to evolve and diversify over the succeeding millions and tens of millions of years. For example, the Ordovician extinction enabled siliceous sponges and tabulate corals to diversify, the Devonian event allowed ray-finned fishes (e.g. salmon, mackerel, cod, tuna, grouper and carp) to diversify, and the K-T event diversification of birds, mammals and spiny-rayed fishes (e.g. oarfish and flying fish).

In passing, if you wish to learn more about the main extinctions, I recommend Courtillot (1999), Schulte et al (2010) and Hull (2015). In particular, Hull discusses mechanisms for re-diversification in the aftermath of mass extinctions that coincides with widespread changes in global ecosystems in the hundreds of thousands and millions of years following the event. Environmental disturbance and ecological change during the extinction perturb the dynamic equilibrium of the earth system. As species and ecosystems re-develop, earth system feedbacks control the direction, nature, and timing of ecosystem change. Hull tells us that, following the loss of taxa, we can identify long intervals of ecological upheaval that create unique ecosystems and regimes. She also says that the pacing and duration of ecosystem change following extinction events suggests strong ties between the biosphere and geosphere, and a macro-evolutionary driver - earth system succession. Succession involves directional changes in ecosystem structure that arise from shifts in the presence and relative abundance of different species over time.

The geological time scale is constantly being reviewed, revised and refined. Most of the subdivisions in the time scale are based on fossil extinctions or originations. Because the timescale was first established in the Northern Hemisphere, it is based mainly on European and North America fossils and has been difficult to apply in New Zealand. For this reason, New Zealand still has its own geological time scale. However, in recent years, considerable efforts by paleontologists at GNS Science have successfully integrated the New Zealand and International Geological Time Scales. Raine et al (2015) and GNS Science (2015) describe this work in detail.

The Limits of our Minds

For those who find evolution difficult to accept, perhaps the main problem lies in the inherent limits of the human mind in comprehending the vastness of time and the numbers of generations available for the evolutionary process to play out. We must also take account of the enormous number of different physical and geochemical environments that nature has made available on the Earth for the creation of amino acids and other building blocks of life. As humans, we live in the here and now, and it remains beyond our ability to comprehend fully the huge span of time that has elapsed since our Earth was formed and the time available for life to evolve and diversify.

Acknowledgements

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