Ancestor of all life on Earth evolved earlier than we thought, according to our new timescale

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Earth's Pacific Ocean seen from the International Space Station. Credit: NASA

Science may have enabled us to travel in space and trace the history of the entire universe, but it has not yet been able to answer exactly how and when life first arose on our planet. Traditionally, scientists have used the fossil record to try to answer these questions. Yet, as palaeontologists are all too aware, fossils are increasingly hard to find as we move backwards in time.

In fact, we don't have a lot of rock available to study that is older than two and a half billion years. This is due to the Earth's rock recycling system in which old rocks are destroyed through weathering processes, with the remains getting recycled into new rocks. This causes any rocks that we do have to be highly reworked from their original composition. Often they don't contain any biological remains at all. Even the rare fossils that we do find are often very difficult to identify and cannot be easily linked to any specific group of modern organisms.

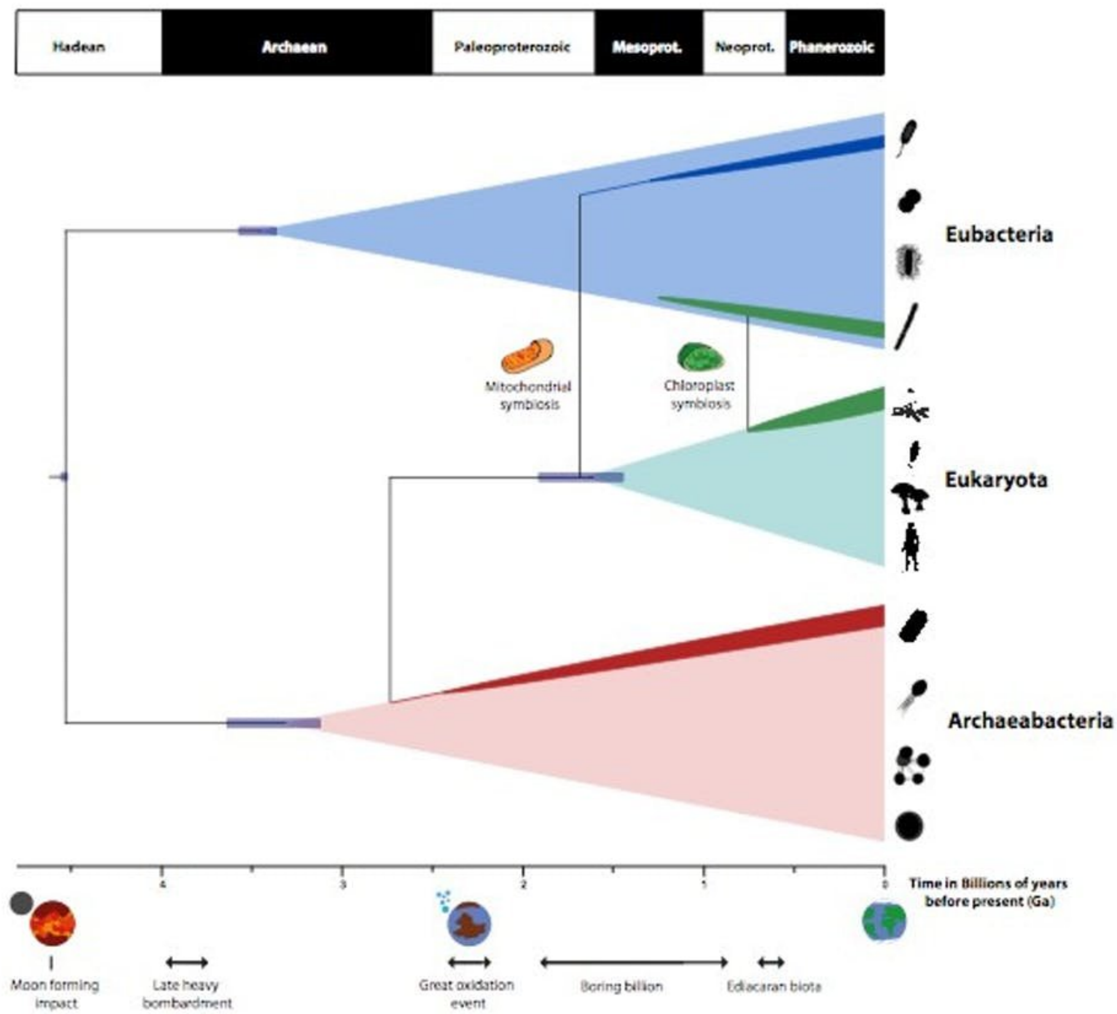
In our new study, published in *Nature Ecology and Evolution*, we decided to try and approach the construction of a timescale for life in a new way. This involved using the wealth of genetic data that we now have for organisms living today and applying a molecular clock, a method to decipher the past by reading the stories written in the genes of living organisms.

All life inherits genetic information from the previous generation, and this gradually changes over time as evolutionary events take place. The methodology works on the basis that the differences in the genomes of two extant (living) species, for example a human and a bacterium, have accumulated in a manner that is roughly proportional to the time since they had a common ancestor. Fossils still play a vital role in this approach by acting as a rough guide to the age of common ancestors, and the molecular clock is used to update these estimates.

Our study combines the molecular data of 29 genes from a total of 102 living organisms (we also used nine fossils for calibration). The living organisms come from right across the tree of life – including bacteria, archaea (single-celled microorganisms) and eukaryotes (multi-celled organisms such as plants and animals).

Including fossils in the process is vital to the analysis because they help to link the events in real time. Fossils tell us that a lineage must have existed prior to the age of the fossil, simply because the fossil is there. This method is most important for the reconstruction of life at its earliest points, because we have so little fossil material to work with. However, until now, this is precisely where it has been applied the least.

Our results – a timescale for the origin and evolution of life – do come with fairly large uncertainties on the age estimates for each of the nodes, the places on the tree where species have a common ancestor. This is especially true for the most ancient parts of the tree and those parts where we have the least data, either fossil or molecular.



A timescale for the evolution of life on Earth summarising the findings of the new study. Credit: University of Bristol

However, the fact that we capture uncertainty is promising, as it indicates that our timescale is not over confident by showing precise, but false, ages. Instead it means that as new extant lineages and fossils continue to be discovered, they can be added to the analysis to both refine and update it – possibly resulting in a higher degree of precision in the future.

The ancestor of all organisms

We find that the "last universal common ancestor" – a hypothetical very early single cell from which all life on Earth descended – existed prior to the "late heavy bombardment". This was a period of intense meteor bombardment sustained by our planet about 3.9 billion years ago. This is significantly earlier than the currently accepted oldest fossil evidence would suggest (estimating 3.5-3.8 billion years ago).

The oldest confirmed fossils are from about 3.4 billion years ago, while the oldest potential fossils have been found on Greenland and date back to about 3.8 billion years ago. There's also a suggestion that carbon found in a 4.1 billion-year-old mineral called zircon could be biological in nature. However, scientists have so far been unable to confirm that.

Some researchers think it would have been impossible for life to survive the late heavy bombardment, so that our oldest ancestor must be from after this phase. There are claims that the event would have sterilised the plants and vaporised any water around at the time. However, there are some recent mathematical models which suggest that pockets suitable for life could have remained.

We found that the crown groups of the two main lineages of life – bacteria and archaea – appeared almost one billion years after the last common universal ancestor. Eukaryotes, on the other hand, diverged relatively late in Earth's history, about 1.8 billion years ago. This finding is consistent with previous studies.

Our timescale also allowed us to look at ancient events such as the "mitochondrial endosymbiosis" – the process which formed the mitochondria, the organelles that power our cellular respiratory systems.

This important event in the history of the eukaryotes occurred close to when they first appeared, suggesting that it helped to drive their subsequent rapid spread.

We hope that our study will be a good starting point for probing the mysteries of evolution at this extremely early time in Earth's history.

More information: Holly C. Betts et al. Integrated genomic and fossil evidence illuminates life's early evolution and eukaryote origin, *Nature Ecology & Evolution* (2018). DOI: 10.1038/s41559-018-0644-x

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