The earliest period in Earth's history is known as the Hadean, after Hades, the Greek god of the dead. The Hadean is defined as the period between the origin of the Earth up to the first appearance of life. Fossils provide our only direct evidence for when life appeared on Earth. They are found in sedimentary rock, which is rock formed when fine particles of mud, sand, or dust entombed an organism before it can be eaten by other organisms. Hunters of fossils (paleontologists) do not search for fossils randomly but use geological information to identify outcroppings of sedimentary rocks of the specific age they are studying in order to direct their explorations.

Geologists recognized that fossils of specific types were associated with rocks of specific ages. This correlation was so robust that rocks could be accurately dated based on the types of fossils they contained. At the same time, particularly in a world that contains young earth creationists who claim that Earth was formed less than ~10,000 years ago, it is worth remembering both the interconnectedness of the sciences and that geologists do not rely solely on fossils to date rocks. This is in part because many types of rocks do not contain fossils. The non-fossil approach to dating rocks is based on the physics of isotope stability and the chemistry of atomic interactions. It uses the radioactive decay of elements with isotopes with long half-lives, such as \(^{235}\)Ur (uranium) which decays into \(^{207}\)Pb (lead) with a half-life of ~704 million years and \(^{238}\)Ur which decays into 206 Pb with a half-life of ~4.47 billion years. Since these two Pb isotopes appear to be formed only through the decay of Ur, the ratios of Ur and Pb isotopes can be used to estimate the age of a rock, assuming that it originally contained Ur.

In order to use isotope abundance to accurately date rocks, it is critical that all of the atoms in a mineral measured stay there, that none are washed in or away. Since Ur and Pb have different chemical properties, this can be a problem in some types of minerals. That said, with care, and using rocks that contain chemically inert minerals, like zircons, this method can be used to measure the age of rocks to an accuracy of within ~1% or better. These and other types of evidence support James Hutton’s (1726-1797) famous dictum that Earth is ancient, with "no vestige of a beginning, no prospect of an end."46 We know now, however, that this statement is not accurate; while very, very old, Earth had a
beginning, it coalesced around ~5 billion years ago, and it will disappear when the sun expands and engulfs it in about ~5.5 billion years from now.\(^{47}\)

Now, back to fossils. There are many types of fossils. Chemical fossils are molecules that, as far as we know, are naturally produced only through biological processes.\(^{48}\) Their presence in ancient rock implies that living organisms were present at the time the rock formed. Chemical fossils first appear in rocks that are between \(~3.8\) to \(~3.5 \times 10^9\) years old. What makes chemical fossils problematic is that there may be non-biological but currently undiscovered or unrecognized mechanisms that could have produced them, so we have to be cautious in our conclusions.

Moving from the molecular to the physical, there are what are known as trace fossils. These can be subtle or obvious. Organisms can settle on mud or sand and make impressions. Burrowing and slithering animals make tunnels or disrupt surface layers. Leaves and immobile organisms can leave impressions. Walking animals can leave footprints in sand, mud, or ash. How does this occur? If the ground is covered, compressed, and converted to rock, these various types of impressions can become fossils. Later erosion can then reveal these fossils. For example, if you live near Morrison, Colorado, you can visit the rock outcrop known as Dinosaur Ridge and see trace fossil dinosaur footprints; there may be similar examples near where you live.

We can learn a lot from trace fossils, they can reveal the general shape of an organism or its ability to move or to move in a particular way. To move, an organism must have some kind of muscle or alternative mobility system and probably some kind of nervous system that can integrate information and produce coordinated movements. Movement also suggests that the organisms that made the trace had something like a head and a tail. Tunneling organisms are likely to have had a month to ingest sediment, much like today’s earthworms - they were predators, eating the microbe they found in mud.

In addition to trace fossils, there are also the type of fossils that most people think about, which are known as structural fossils, namely the mineralized remains of the hard parts of organisms such as teeth, scales, shells, or bones. As organisms developed hard parts, fossilization, particularly of organisms living in environments where they could be buried within sediment before being dismembered and destroyed by predators or microbes, became more likely.

Unfortunately for us (as scientists), many and perhaps most types of organisms leave no trace when they die, in part because they live in places where fossilization is rare or impossible. Animals that live in woodlands, for example, rarely leave fossils. The absence of fossils for a particular type of organisms does not imply that these types of organisms do not have a long history, rather it means that the conditions where they lived and died or their body structure is not conducive to fossilization. Many types of living organisms have no fossil record at all, even though, as we will see, there is molecular evidence that they arose tens to hundreds of millions of years ago.

**Contributors and Attributions**

- [Michael W. Klymkowsky](https://bio.libretexts.org/Bookshelves/Cell_and_Molecular_Biology/Book%3A_Biofundamentals_(Klymkowsky_and_Cooper)/02%3A_Cell_Biology/2.10%3A_Cell_Signaling_Systems) (University of Colorado Boulder) and [Melanie M. Cooper](https://bio.libretexts.org/Bookshelves/Cell_and_Molecular_Biology/Book%3A_Biofundamentals_(Klymkowsky_and_Cooper)/02%3A_Cell_Biology/2.10%3A_Cell_Signaling_Systems) (Michigan State University) with significant contributions by Emina Begovic & some editorial assistance of Rebecca Klymkowsky.