

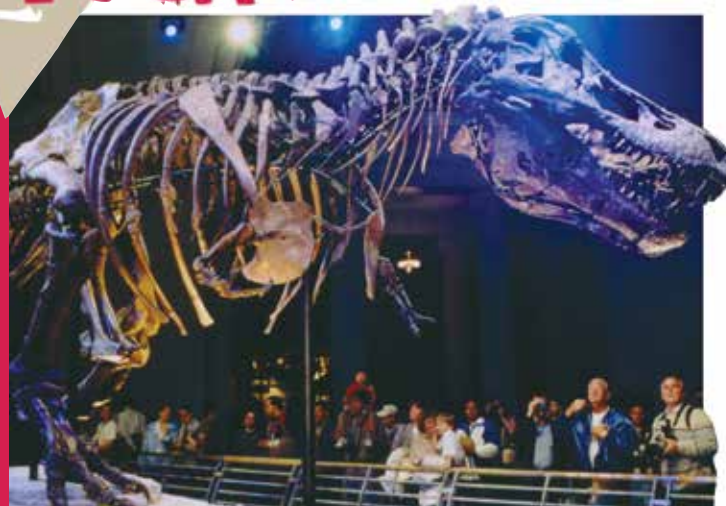


Scan the image on the right with the LinkReader mobile app to watch a video on how fossils are prepared for museum exhibitions.



By Gail Mitchell Emilsson and Michael Tennesand

When you see the skeleton of an animal that died millions of years ago—from a small fish to a huge dinosaur—you may wonder how the bones that make up the skeleton lasted so long and did not decay. **In fact, these are not actually bones, but rocks that formed in or around the bones.** More surprisingly, these bone-looking rocks, also called fossils, are very difficult to form, even though there is a vast record of life that has been preserved in the form of fossils. So, how is it that some living beings seem to avoid decomposition and leave evidence of what they looked like and how they lived millions and millions of years ago? And how exactly are fossils made?



The *T. rex* dinosaur named SUE was unveiled at the Field Museum in Chicago, Ill., on May 17, 2000.

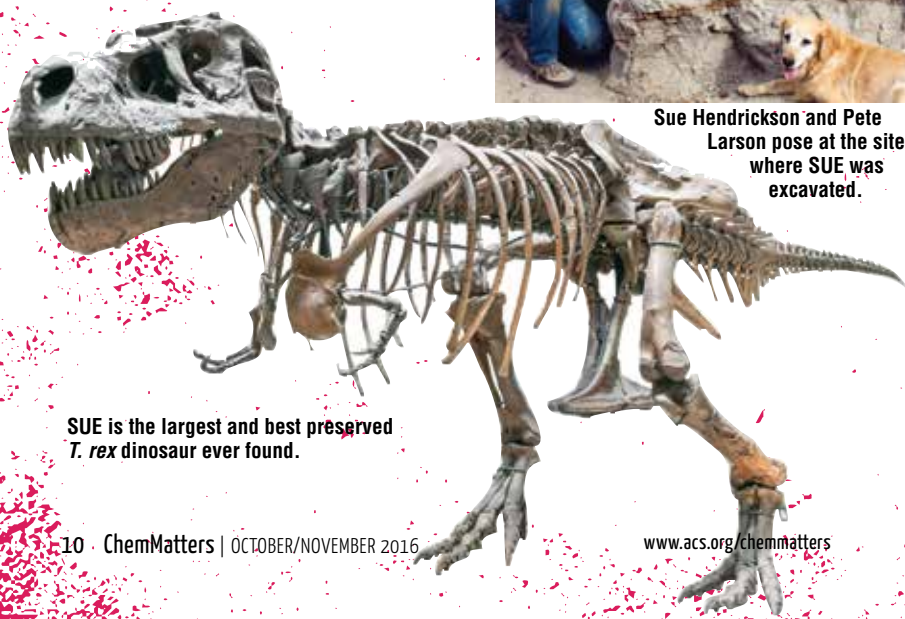


Sue Hendrickson and Pete Larson pose at the site where SUE was excavated.

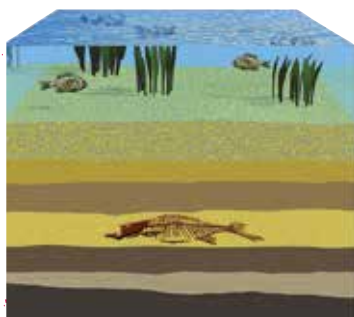
Meet SUE

Consider the most recognizable examples of fossils—those from dinosaurs. One notable example is a *Tyrannosaurus rex* named SUE. In the years that followed its death, the body of this *T. rex* decomposed, but not all of its remains were lost. Some underwent physical and chemical processes that converted them into rock. The typical natural processes that lead to the total decomposition of a dying body were interrupted, and a rock-like copy of the skeleton was formed that lasted for millions of years until August 1990 when paleontologist Sue Hendrickson discovered it.

The dinosaur was named SUE in her honor (even though no one knows whether the dinosaur was actually female). At 12.9 meters (40.5 feet) long, 4 meters (13 feet) tall at the hip, and with 90% of its bone volume recovered, SUE is the largest and most complete fossilized *T. rex* ever found.



SUE is the largest and best preserved *T. rex* dinosaur ever found.



Fossils can form on land, in river valleys, or at the bottom of the ocean, but the best preserved fossils are those that form at the bottom of river valleys.

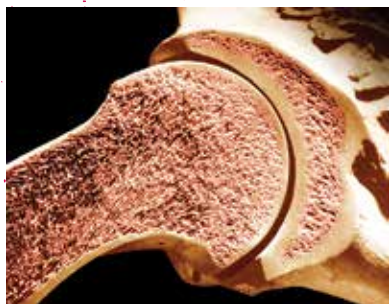
normal decomposition process is slowed under sand or mud, sometimes allowing the process of fossilization to take place.

Fossil formation

So, how did SUE's fossils form? First, its body started decomposing, just as all organisms do when they die. Only a few hours after its death, red blood cells started releasing iron, cells along the digestive tract started leaking digestive enzymes, and muscle cells leaked calcium, causing the muscles to contract and the body to stiffen. All of these changes resulted in a soup of various types of molecules that fed micro-organisms—mostly bacteria—already present in SUE's guts. These bacteria started multiplying while producing putrescine and cadaverine, two foul-smelling compounds that attract insects and larger scavengers.

But even though SUE's soft tissues were soon lost to continuing decomposition, the rest of its body was probably buried by sand, silt, and mud from the nearby river, allowing most of its bones to become fossils.

Bone is not as dry and lifeless as it may seem. It is actually a porous structure (photo below) that consists of collagen protein embedded with a bone mineral and permeated with living cells, blood vessels, and nerves.



The inside of a bone is porous, so when animals die, minerals may fill in these pores, creating a fossil.

Fossils are the preserved copies of the remains of living organisms. The chance that any living organism will become fossils is quite low. The fossils of sea creatures are more common than those of land creatures, because most fossils start forming after the organism is covered in sand or mud—conditions more common in the ocean. On land, fossil deposition can occur in lakes and bogs. The

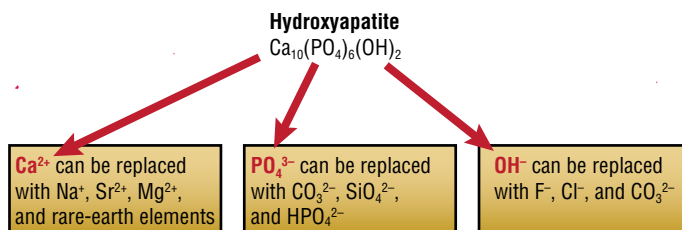


Figure 1. After an animal dies, the bone mineral, which has a molecular structure similar to hydroxyapatite [$\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$], starts to react with chemicals in its environment, and the calcium (Ca^{2+}), phosphate (PO_4^{3-}), and hydroxide (OH^-) ions that make up hydroxyapatite are replaced with other ions, which are shown here. The chemical formula given for hydroxyapatite is the one used to indicate the composition in one unit of the crystal structure.

Collagen provides the bone with strength and flexibility. The bone mineral makes up 70% of bone and is responsible for its characteristic hardness and rigidity. It belongs to a group of minerals known as phosphate minerals. While this bone mineral is maintained during life, after death, it starts to react with chemicals in its environment, and the rest of the bone material becomes mineralized.

How this happens is not completely understood, but scientists agree that the pores and spaces left by the loss of organic material in the bone must be rapidly filled by minerals, or the original bone will simply dissolve. After the spaces in and around the bone are filled, the composition of the bone mineral may change, too, because various ions in it are replaced with other ions from the environment (Fig. 1).

Types of Fossils

There are three main types of fossils: impression fossils, trace fossils, and replacement fossils. This is how each type of fossils forms:

Impression fossils: When the living organism dies, either a cast or a mold is formed. In the case of a mold, mud or sediment covers the body and forms an impression of the organism. When the organism decays, the impression of the body remains. A cast works much the same way, except that the cavity of the impression is filled in by minerals, forming a “replica” image of the organism.

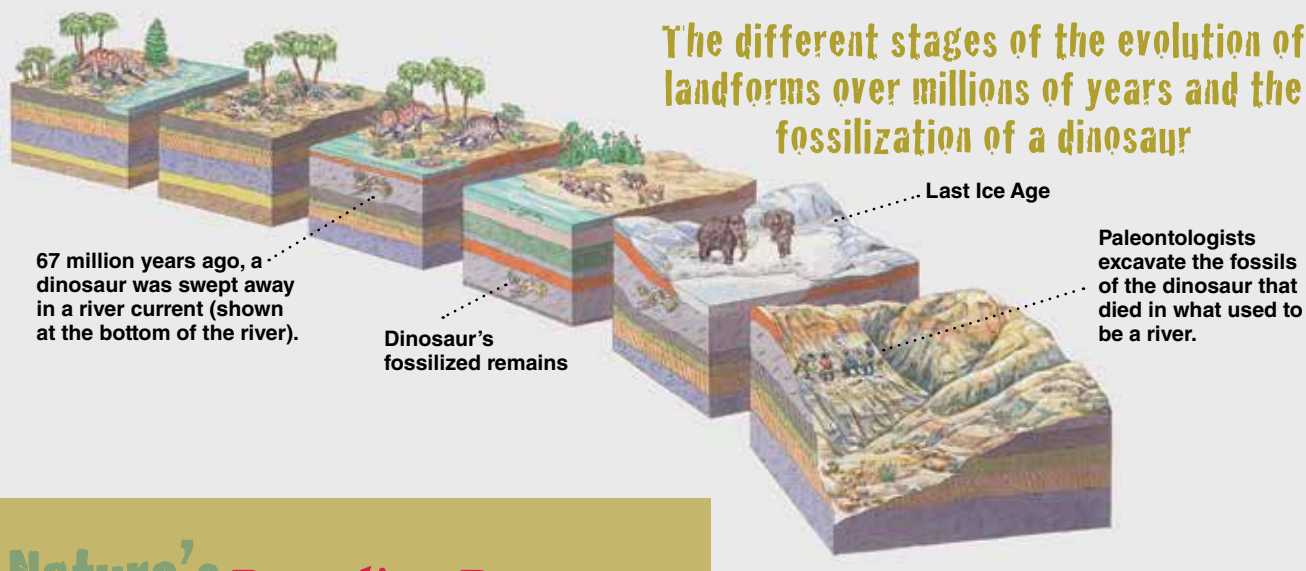
Trace fossils: Trace fossils include any impression or other preserved sign of activity rather than the preserved remains of the body of the actual organism itself. They include footprints, dung, nests, and tooth marks, and they give hints about the behavior of ancient organisms.

Replacement fossils: These fossils are replicas of living beings—such as trees, land animals, and sea creatures—which were trapped in an ocean, lake, or pond, where the once-living beings were covered with silt and where oxygen was mostly excluded, leaving the body intact long enough for fossilization to occur. As they rotted, the organic parts were replaced by hard mineral deposits. The minerals filled in the spaces and created a replacement fossil of the living being.

—Michael Tennesand



The different stages of the evolution of landforms over millions of years and the fossilization of a dinosaur



Nature's Recycling Processes

Billions of organisms have lived on Earth over the past 4 billion years. Some lived for brief minutes or hours, while others survived for hundreds of years. But in the end, all living things die, and most leave no trace behind. So what happens to the bodies of organisms after they die? It is all part of nature's grand recycling plan and the circle of life.


The answers are derived from the law of conservation of matter, which states that matter cannot be created or destroyed. The same goes with the atoms that make up living things. Atoms come together to make molecules and materials that make up organisms. So when organisms die, the matter in their bodies breaks down, or decomposes, and is available for re-use in new ways.

Chemists estimate that one or two atoms that make up your body, right now, were likely part of a dinosaur's body 65 million years ago. Other atoms in your body might have been part of a lily pad or a giant sequoia tree.

—Michael Tennesand

A window to the past

Fossils not only tell us about animals that died millions of years ago but also how animals change over time, whether they disappeared from the surface of the Earth following mass extinctions or whether they migrated from one area to another, revealing climate changes and providing evidence for continental plate movements.

Fossils may also be able to preserve more original material, even protein, than previously thought. If so, new information, such as the presence of certain tissues, could reveal more about when and how certain traits evolved. This information could help us better visualize how the world changed over millions of years. 

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The University of California Museum of Paleontology, Berkeley, The Tyrant Lizards: The Tyrannosauridae: <http://www.ucmp.berkeley.edu/diapsids/saurischia/tyrannosauridae.html> [accessed July 2016].

Gail Mitchell Emilsson is a science writer and a high school teacher in New Haven, Conn. Her latest *ChemMatters* article, "What's in Sunscreens," appeared in the April 2010 issue. **Michael Tennesand** is a science writer and education consultant who lives in Portland, Ore. His latest *ChemMatters* article, "ChemDemos Demystified," appeared in the February/March 2015 issue.

Later, more chemical changes occur. Additional minerals fill the bony pores further, and the blood vessels are replaced with minerals called siliceous siltstone and calcite.

While the minerals of the bones are being replaced, rock starts forming around the former bone. The time it takes for fossils to form varies from a few years to thousands of years. During this time, small bones are usually washed away or crushed by accumulating sediment. That is another reason why SUE is so remarkable—it is the first *T. rex* where tiny, delicate ear bones, called stapes, have been recovered, showing that SUE's ear structure had bones similar to ours.

