

Ancient brains: A look inside the extraordinary preservation of a 310-million-year-old nervous system

July 27 2021, by John Paterson Et Al.

Credit: Javier Ortega-Hernández, Author provided

Charles Darwin famously discussed the "imperfections" of the geological record in his book *On The Origin of Species*. He correctly pointed out that unless conditions are just right, it's unlikely for

organisms to be preserved as fossils, even those with bones and shells.

He also said "no organism wholly soft can be preserved."

However, after more than a century of fossil hunting since his book was published, we now know the preservation of soft creatures is indeed possible—including some of the most fragile animals, such as [jellyfish](#).

But what about the really delicate anatomy of animals, such as their internal organs? Can they be fossilized too?

Our study, published today in [Geology](#), shows how even the intricate brains of ancient aquatic [arthropods](#) (invertebrates with jointed legs) can be preserved in remarkable detail.

The discovery of a 310 million-year-old horseshoe crab in the US, complete with its brain intact, adds to a recent string of fossil finds which have unearthed some of the oldest arthropods with a preserved [central nervous system](#).

The horseshoe crab fossil we document in our study sheds new light on how these fragile organs—typically prone to very rapid decay—can be preserved with such fidelity.

Brain freeze: how to fossilize an arthropod brain

Most of our knowledge of prehistoric arthropod brains has been sourced from two key types of fossil deposit: amber and those of Burgess Shale-type.

(A) Specimen of the fossil horseshoe crab *Euproops danae* from Mazon Creek, Illinois, USA, preserved with its brain intact. (B) Close-up of brain, as indicated by box in image (A). (C) Reconstruction of *Euproops danae*, including the position and anatomy of the brain. Credit: Russell Bicknell

[Amber](#) is fossilized resin that oozes through tree bark and is known to trap a variety of organisms. The [entombed individuals](#) are commonly represented by arthropods such as insects—made famous in the original [Jurassic Park](#) movie.

These fossils preserve an incredible amount of anatomical detail, as well as [behaviors](#), mainly because very little decay takes place after the organism is rapidly trapped in the resin.

Using sophisticated imaging technology on these amber fossils, paleontologists can study tiny arthropod brains [in 3D at minuscule scales](#). However, the [oldest arthropods in amber](#) only extend back to the Triassic Period (around 230 million years ago).

[Burgess Shale-type deposits](#) are much older, being Cambrian in age (typically 500 to 520 million years old). They contain an abundance of exceptionally preserved marine arthropods.

These fossils are very important as they represent what are unmistakably some of the oldest animals, and can therefore inform us on their origins and earliest evolutionary history. Their remains are primarily preserved as carbon films in mudstone.

A centipede and a neighbouring ant suspended in roughly 23 million-year-old Mexican amber. Credit: Greg Edgecombe

The fossilization process starts with storm-induced mudflows that sweep up the delicate animals and bury them in the seafloor in low oxygen conditions. Over time, the mud turns to stone and is compressed, leaving the animals pancaked in the rocks.

Many Burgess Shale-type arthropod specimens preserve internal organs, especially the gut. But fewer show parts of the central nervous system, such as the optic nerves, ventral nerve cord or the brain.

Mind-boggling preservation

Our new fossil demonstrates arthropod brains can be preserved in an entirely different way. The specimen of the horseshoe crab, *Euproops danae*, comes from the world-famous [Mazon Creek deposit](#) of Illinois, in the US. Fossils from this deposit are preserved within concretions made of an iron carbonate mineral called siderite.

Some of the Mazon Creek animals, such as the bizarre "Tully Monster," are entirely soft-bodied. This suggests special conditions must have been in place to preserve them.

The Cambrian arthropod *Chengjiangocaris kunmingensis* from China. See the bead-like ventral nerve cord preserved in the fossil (A) and its central position in the reconstruction (B). Credit: Javier Ortega-Hernández

We have shown, for the first time, that the Mazon Creek animals were not only molded by the rapid formation of siderite that entombed their entire bodies, but also that the siderite quickly encased their internal soft tissues before they could decompose.

Notably, the brain of *Euproops* is replicated by a white-colored clay mineral called kaolinite. This mineral cast would have formed later within the void left by the brain, long after it had decayed. Without this conspicuous white mineral, we may have never spotted the brain.

A fossil no-brainer

One of the challenges of interpreting ancient arthropod anatomy is the lack of close modern relatives available for comparison. But luckily for us, *Euproops* can be compared to the four species of living horseshoe crabs.

Even to the untrained eye, a comparison of the fossil's nervous system with that of a modern horseshoe crab (below) leaves little question that the same structures are found in both species, despite them being separated by 310 million years.

(A) The fossil and (B and C) interpretive drawings of the *Euproops danae* brain, and (D) the brain of a modern juvenile horseshoe crab, *Limulus polyphemus*.
Credit: (A-C) Russell Bicknell, (D) Steffen Harzsch

The fossil and living nervous systems match up in their arrangements of nerves to the eyes and appendages, and show the same central opening for the esophagus to pass through.

Uncovering these exceptional specimens gives paleontologists a rare glimpse into the deep past, enhancing our understanding of the biology and evolution of long-extinct animals. It seems Charles Darwin need not have been so pessimistic about the fossil record after all.

More information: Russell D.C. Bicknell et al, Central nervous system of a 310-m.y.-old horseshoe crab: Expanding the taphonomic window for nervous system preservation, *Geology* (2021). [DOI: 10.1130/G49193.1](https://doi.org/10.1130/G49193.1)

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